Validation of a CFD model with a triple-lidar system upstream of a wind turbine in complex terrain

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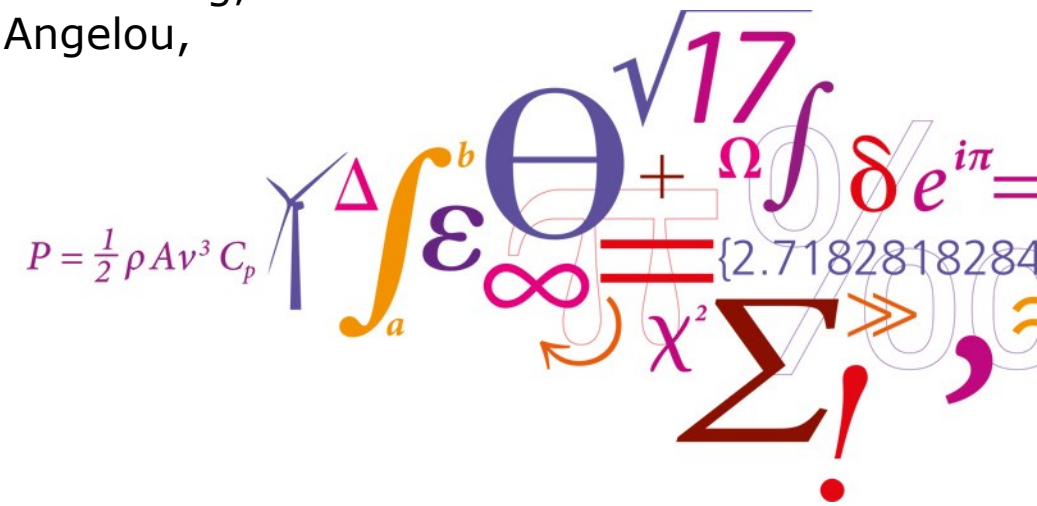
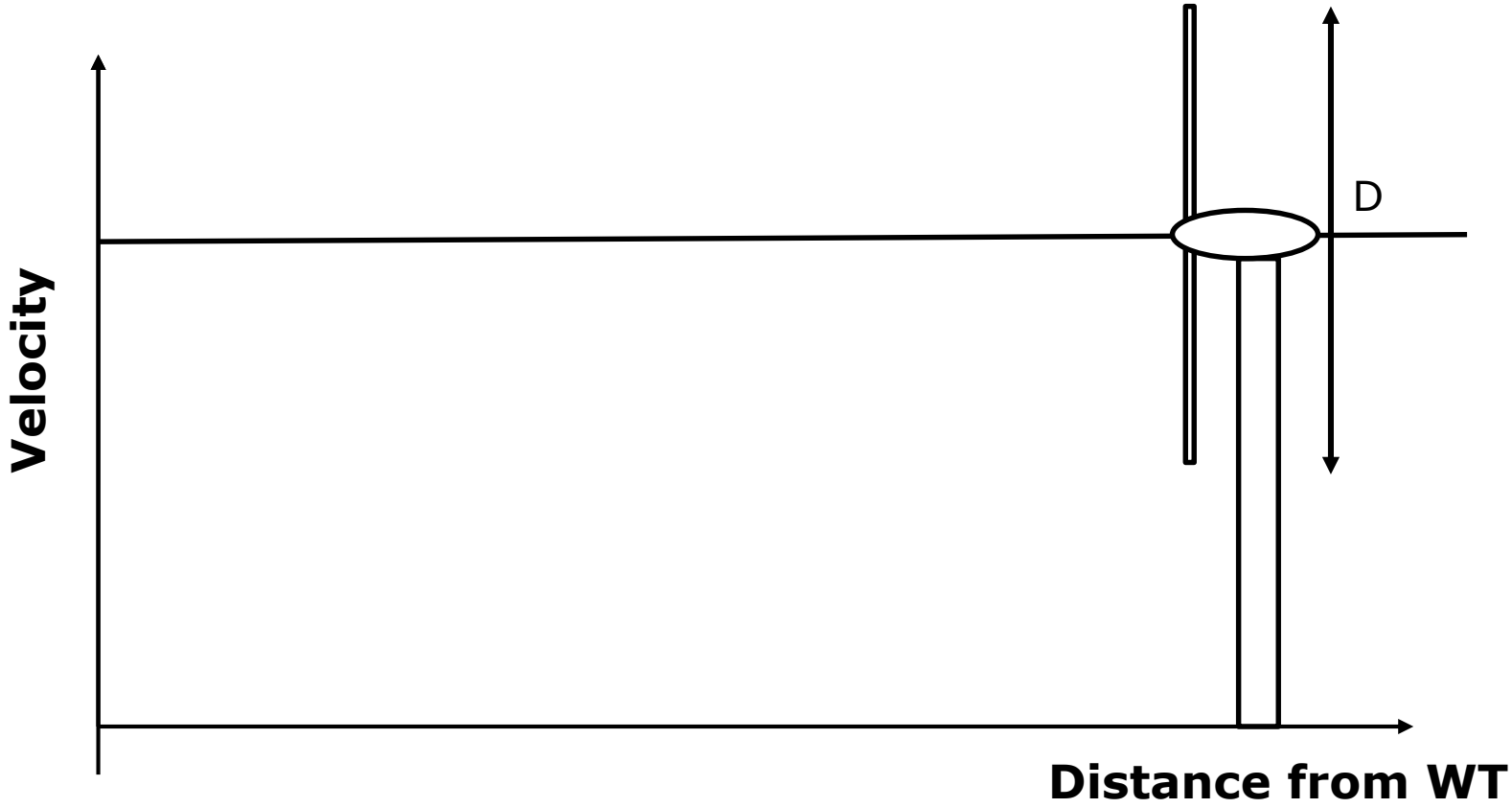


DTU Wind Energy
Department of Wind Energy

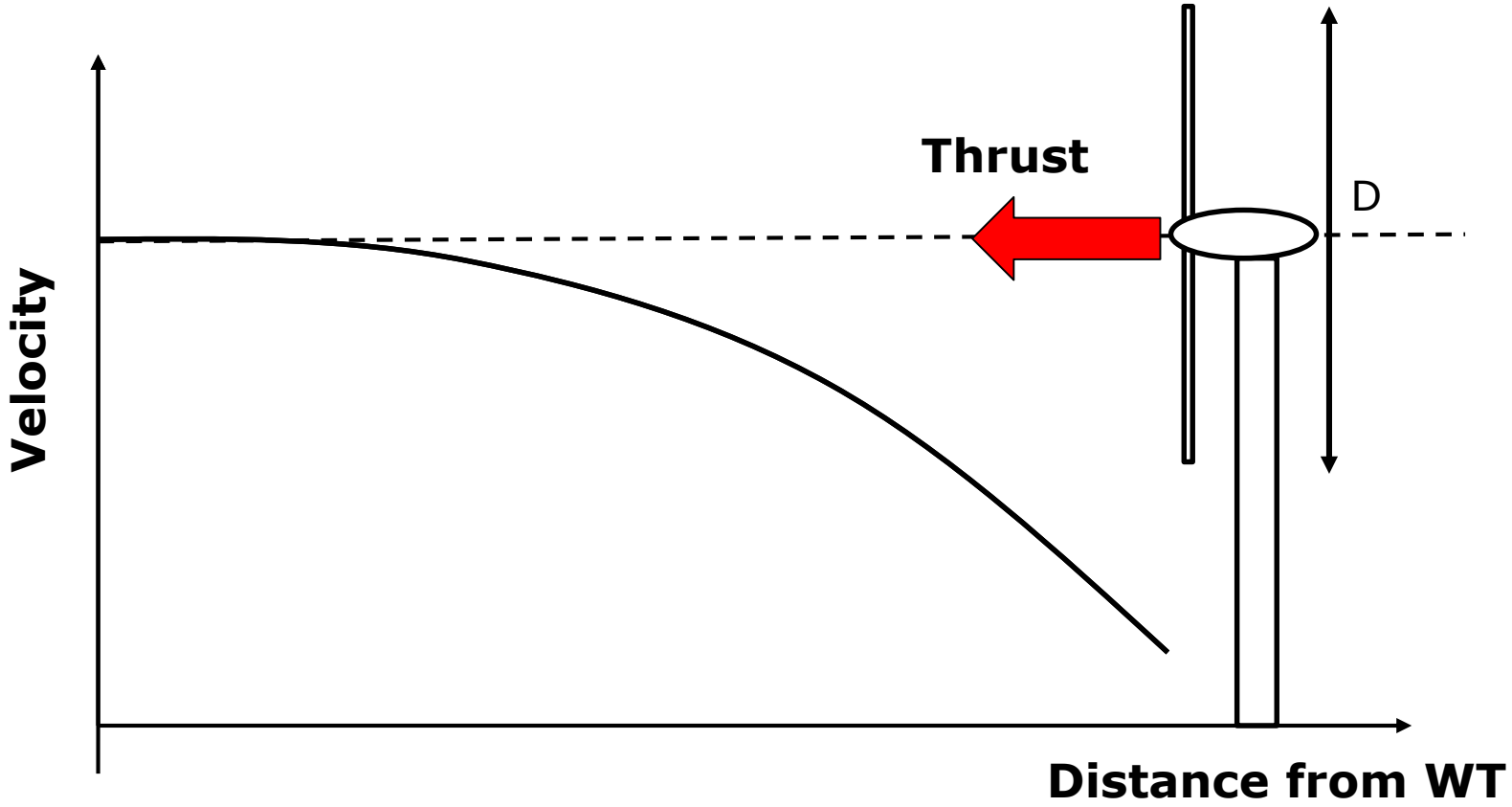
Overview

- The induction zone
- Power curve measurements
- Computational method
- CFD simulations
- Triple-lidar measurements in the induction zone
- CFD – measurement comparison
- Conclusion
- Future work

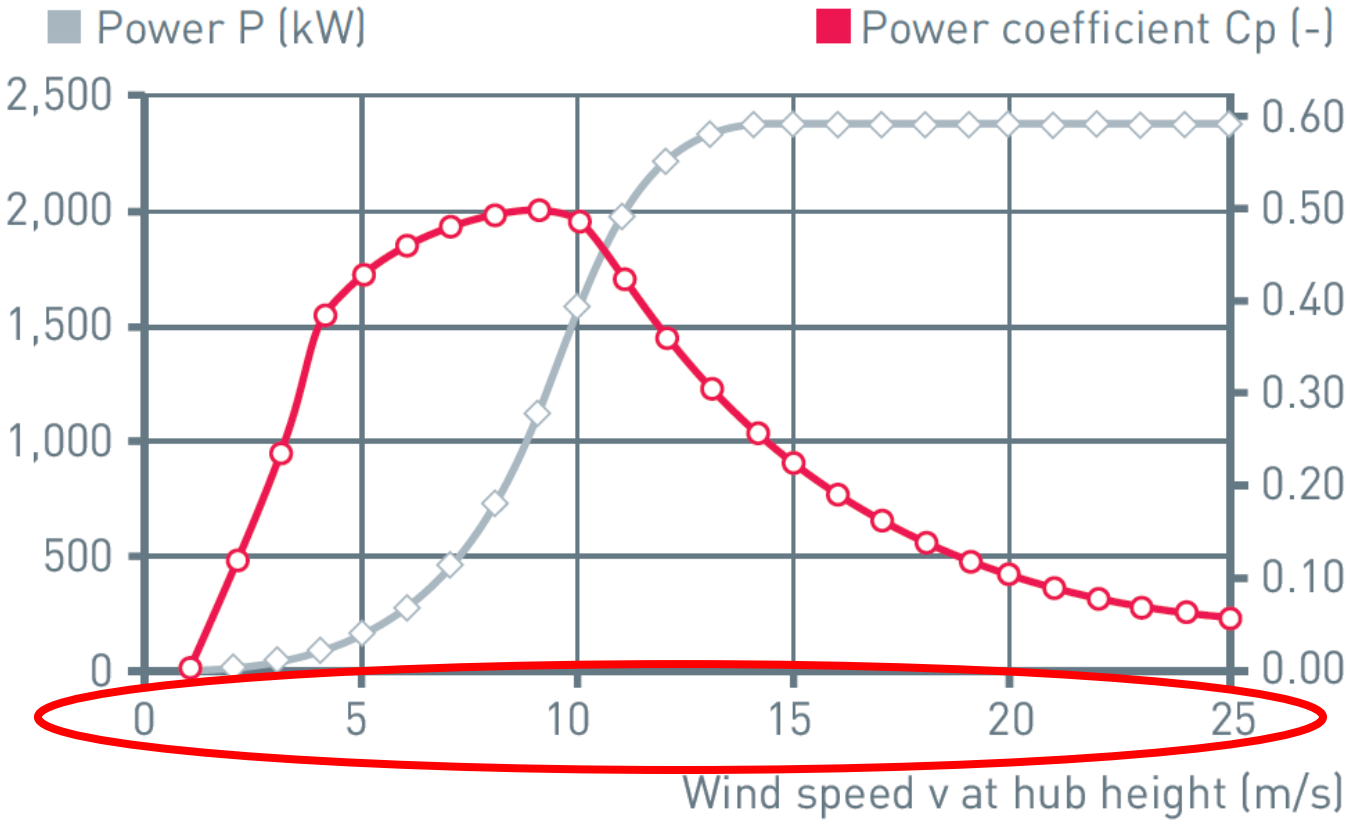
The induction zone



The induction zone



Power curve measurements



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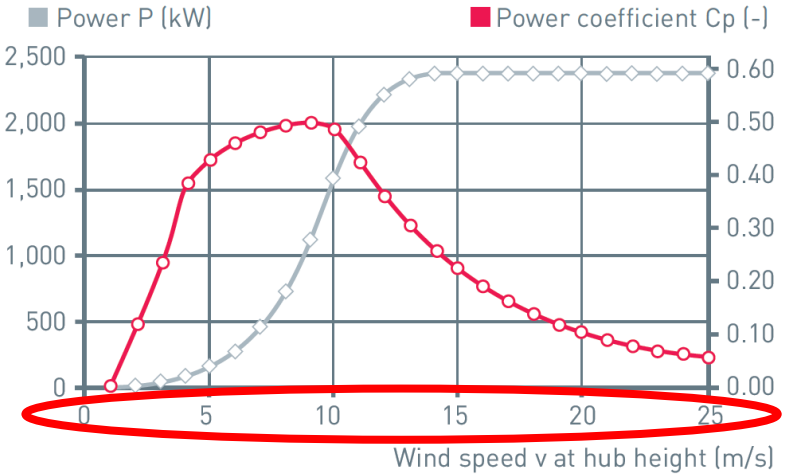

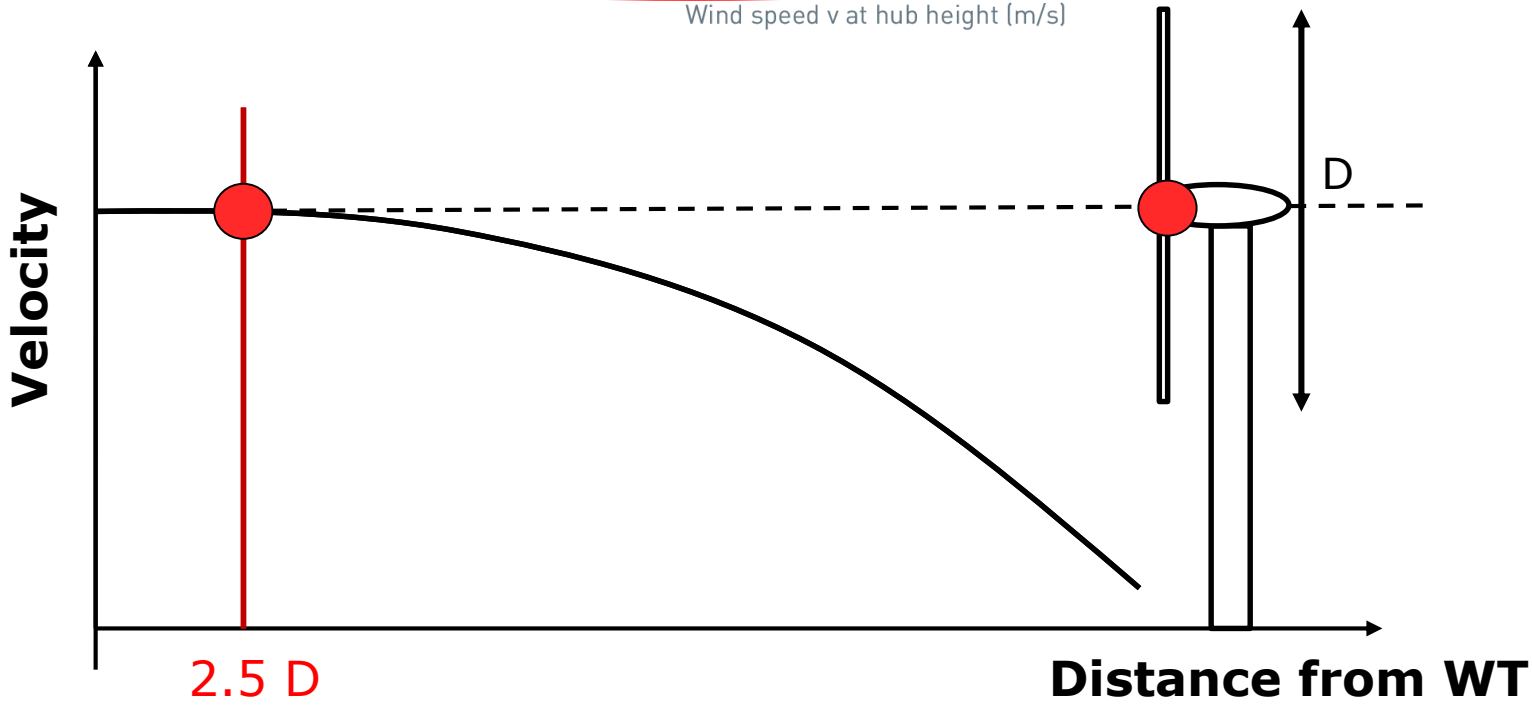

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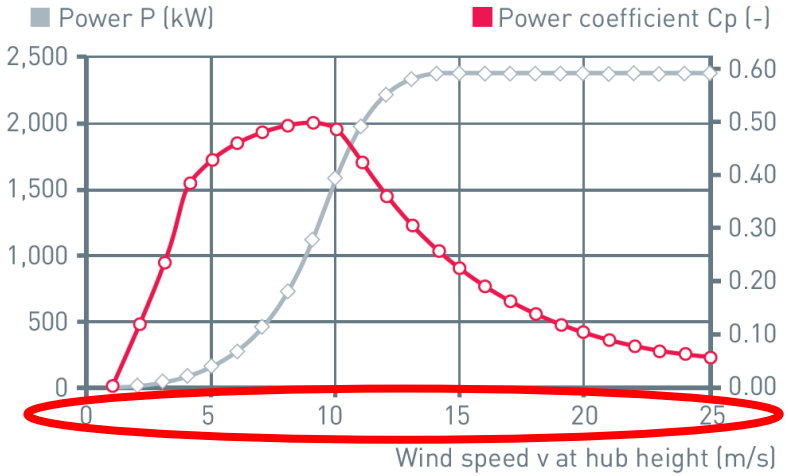
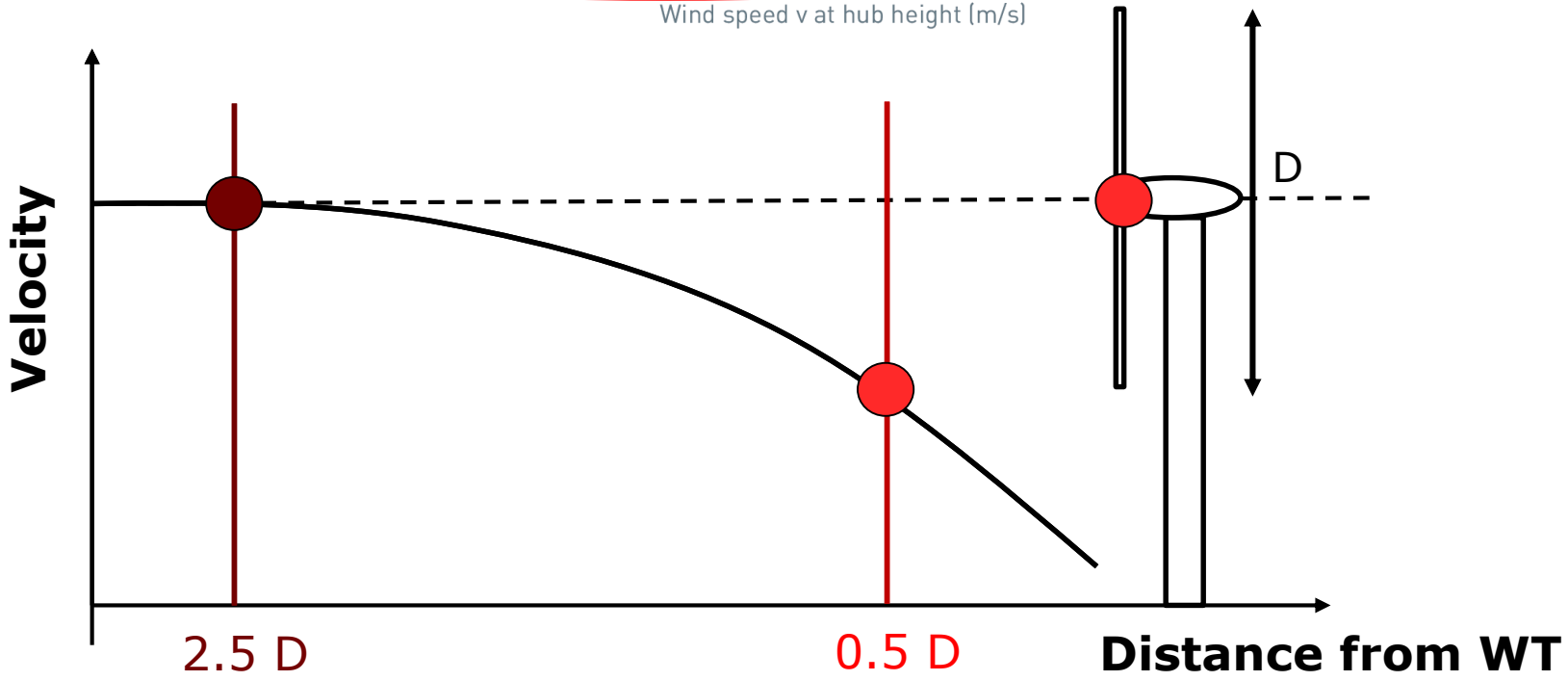
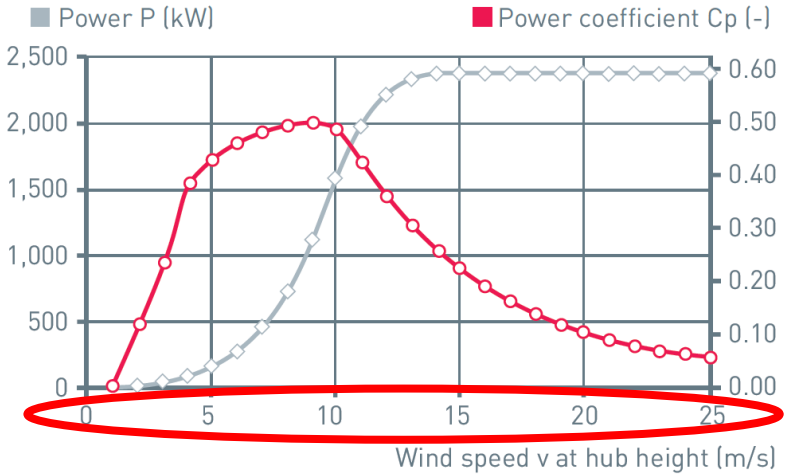
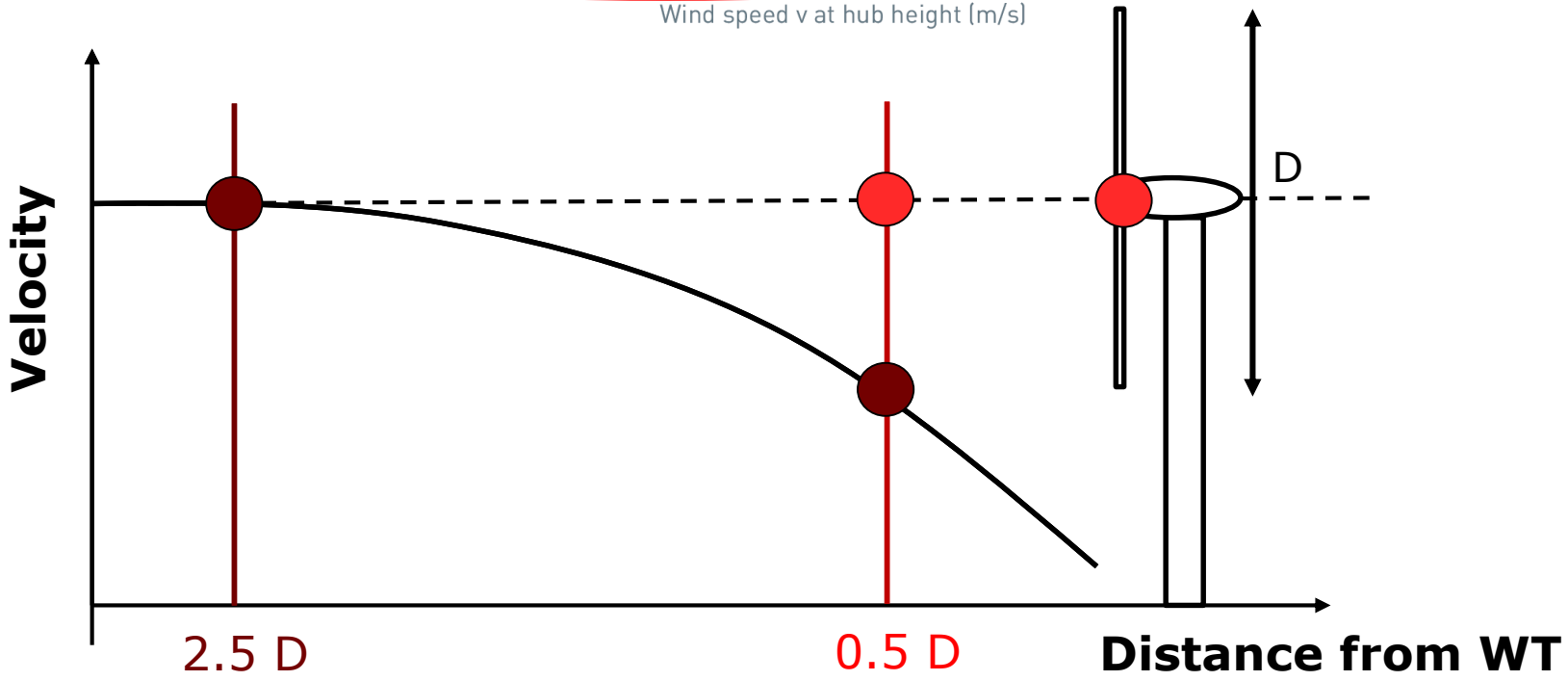


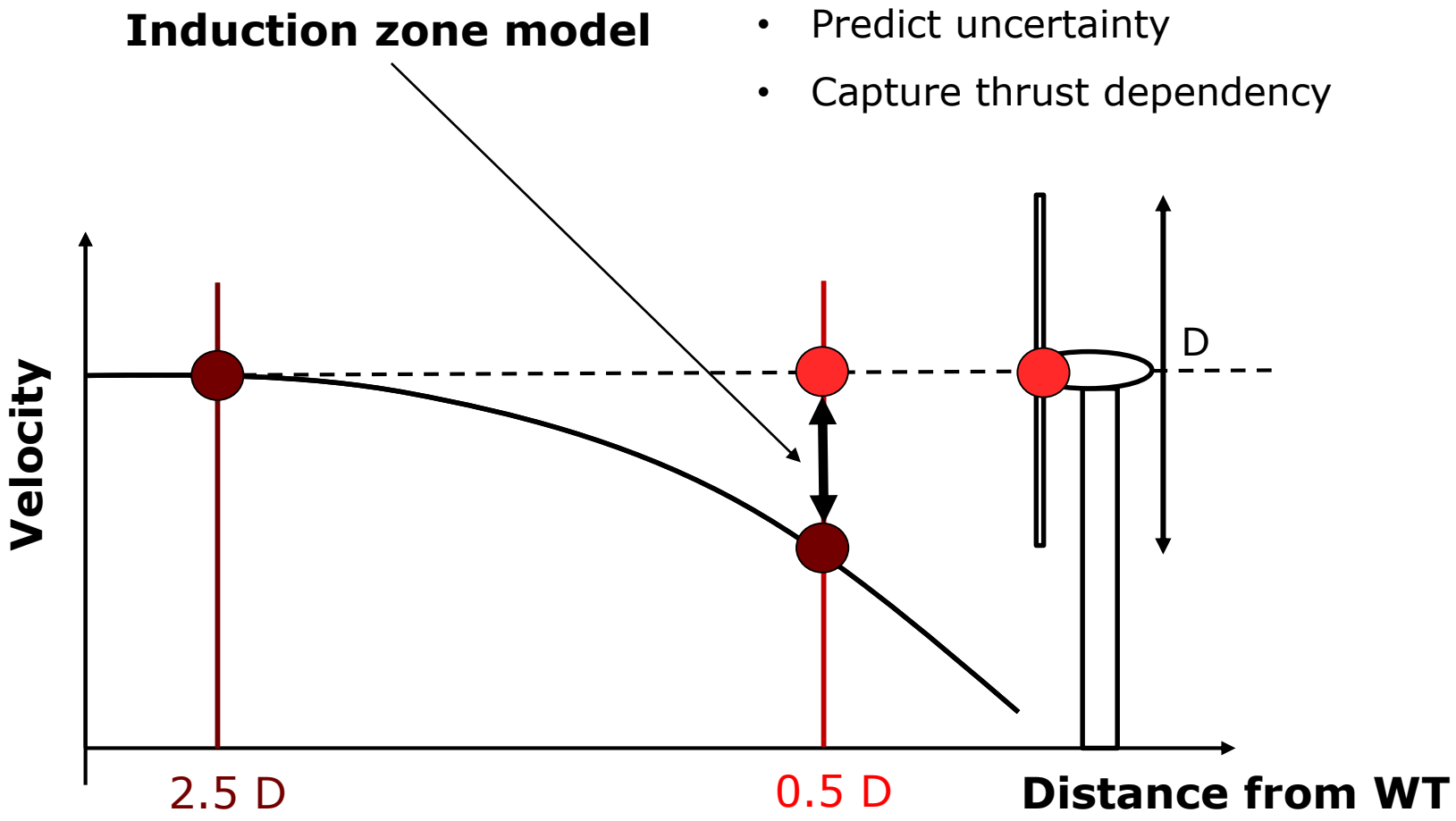


Power curve measurements

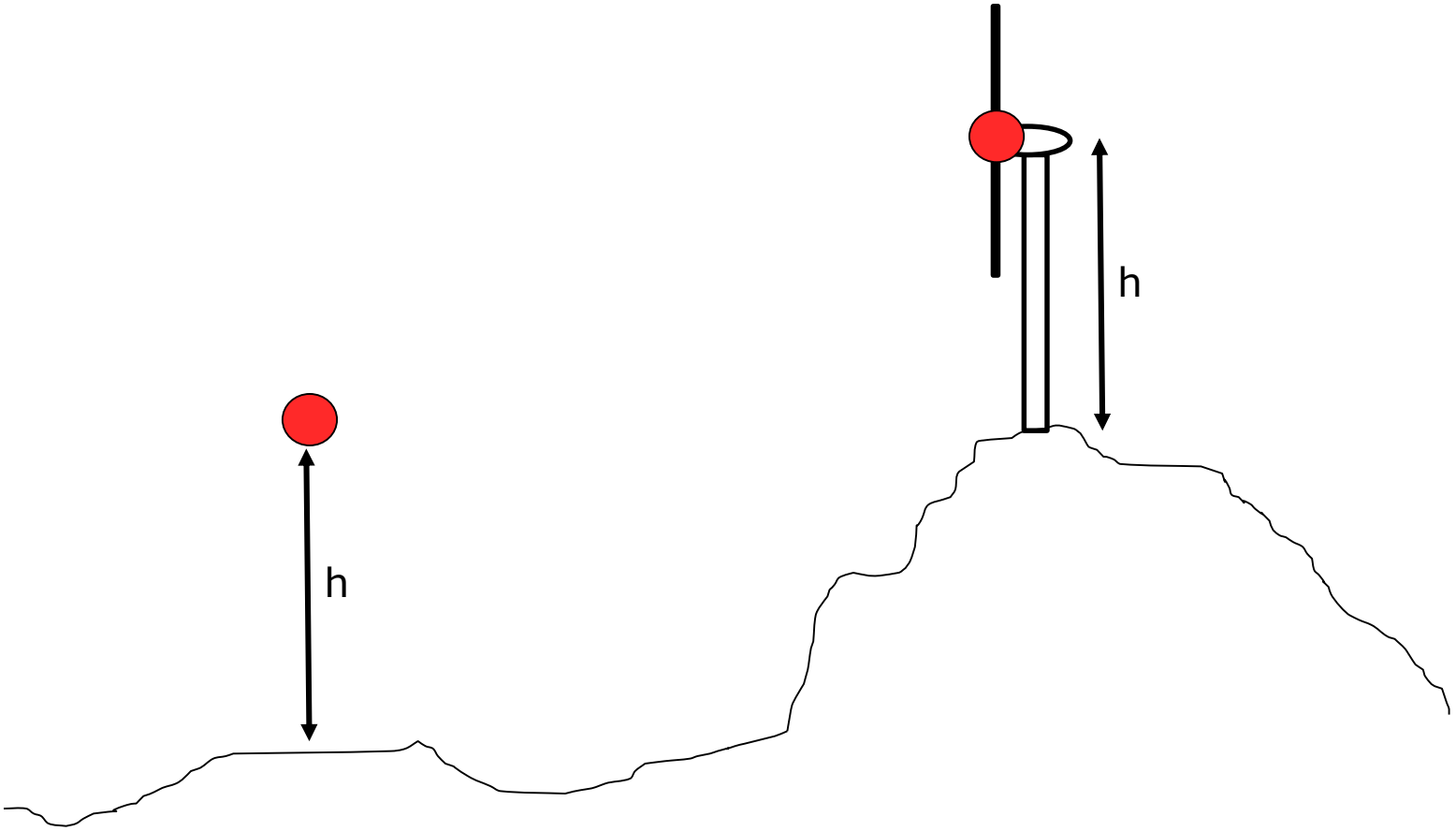




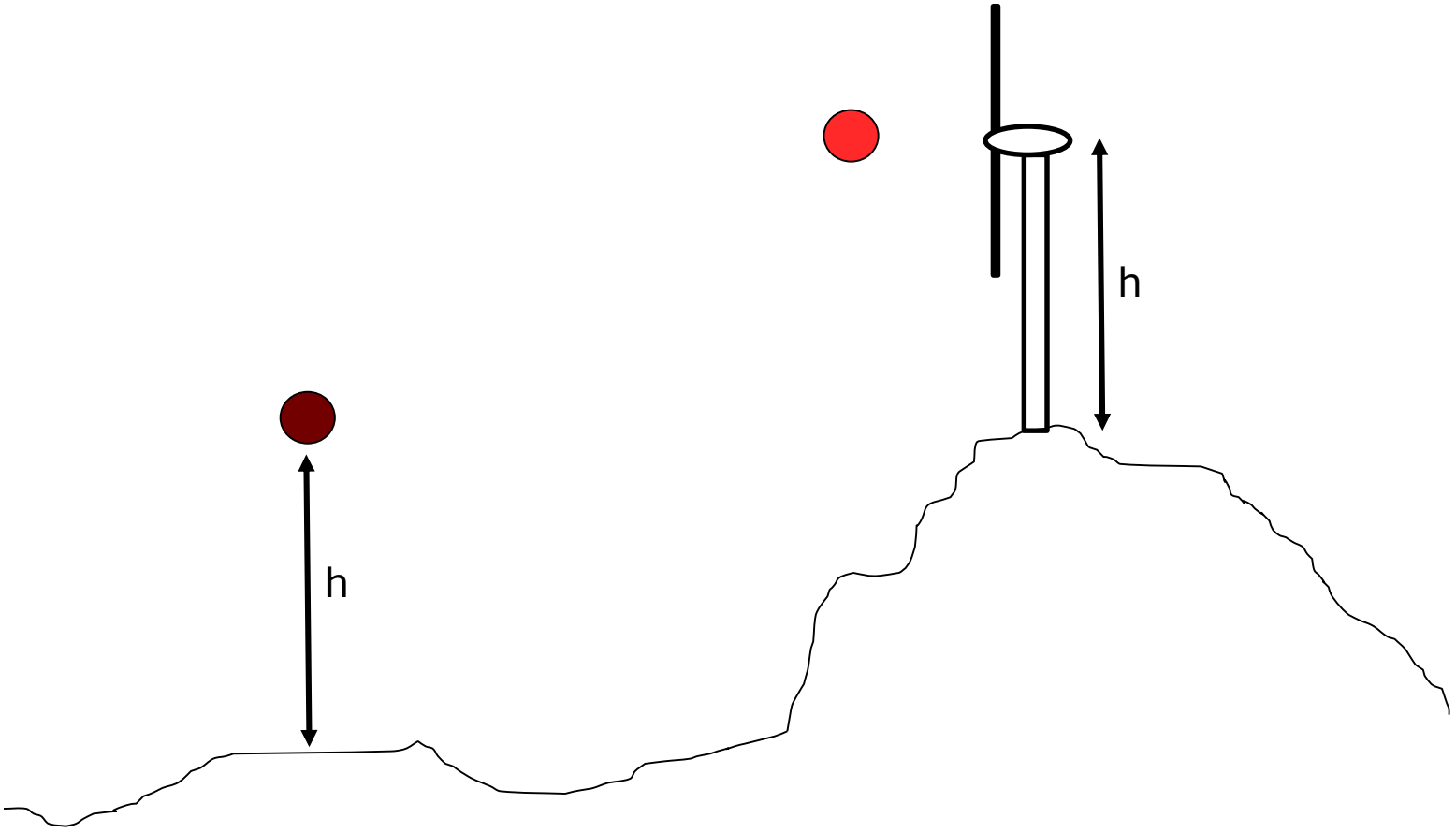
Power curve measurements



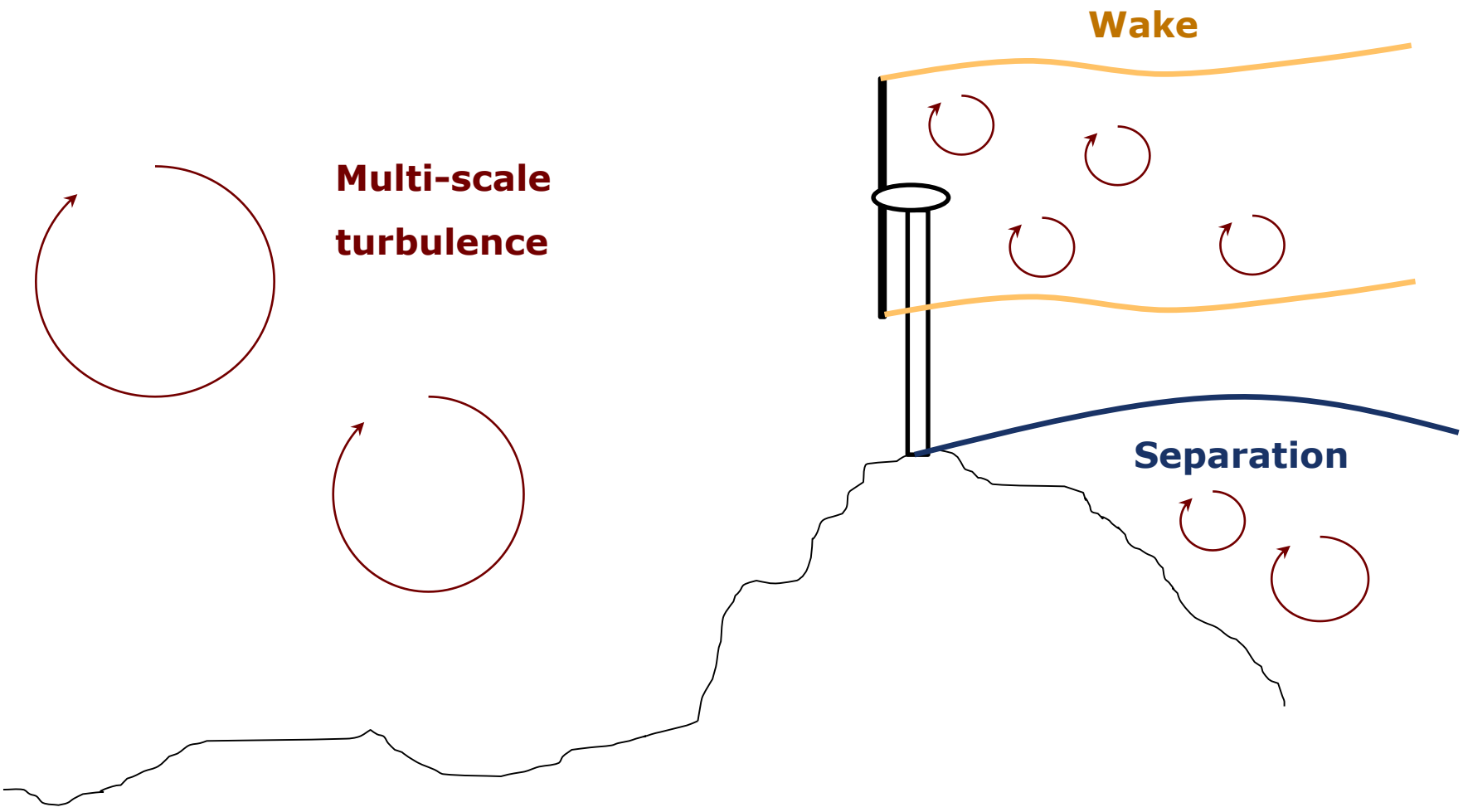
Power curve measurements in complex terrain



Power curve measurements in complex terrain



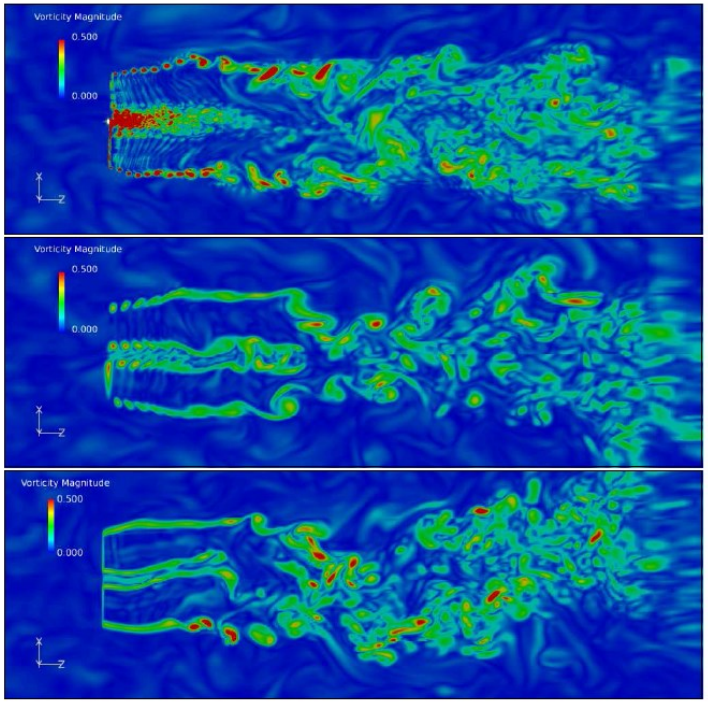
Modeling the induction zone in complex terrain



EllipSys3D

General

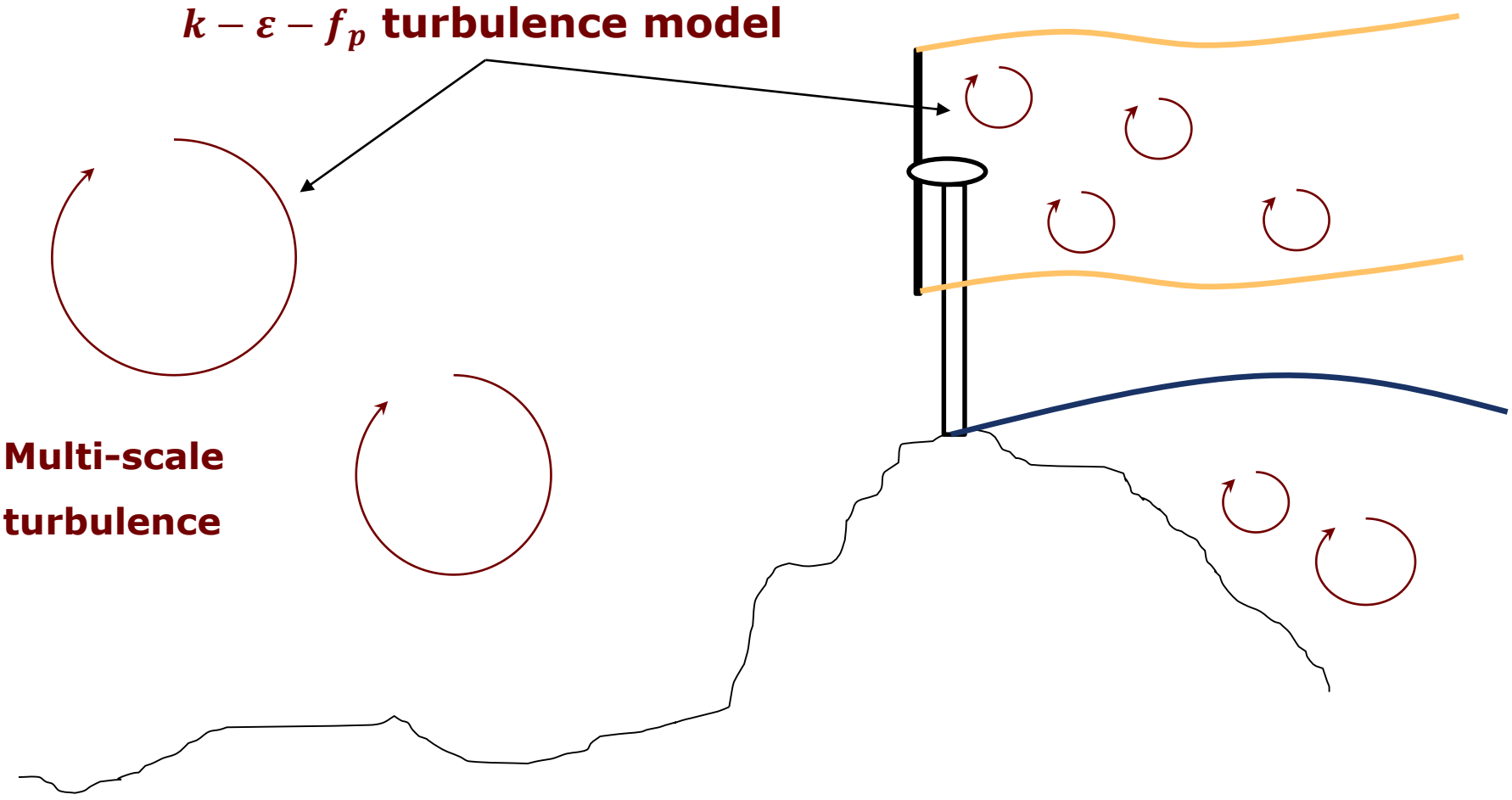
- Multi-purpose finite volume solver
- Block-structured grid with collocated variables
- Highly parallelised
- Body forces are implemented via modified Rhie-Chow algorithm



Complex terrain

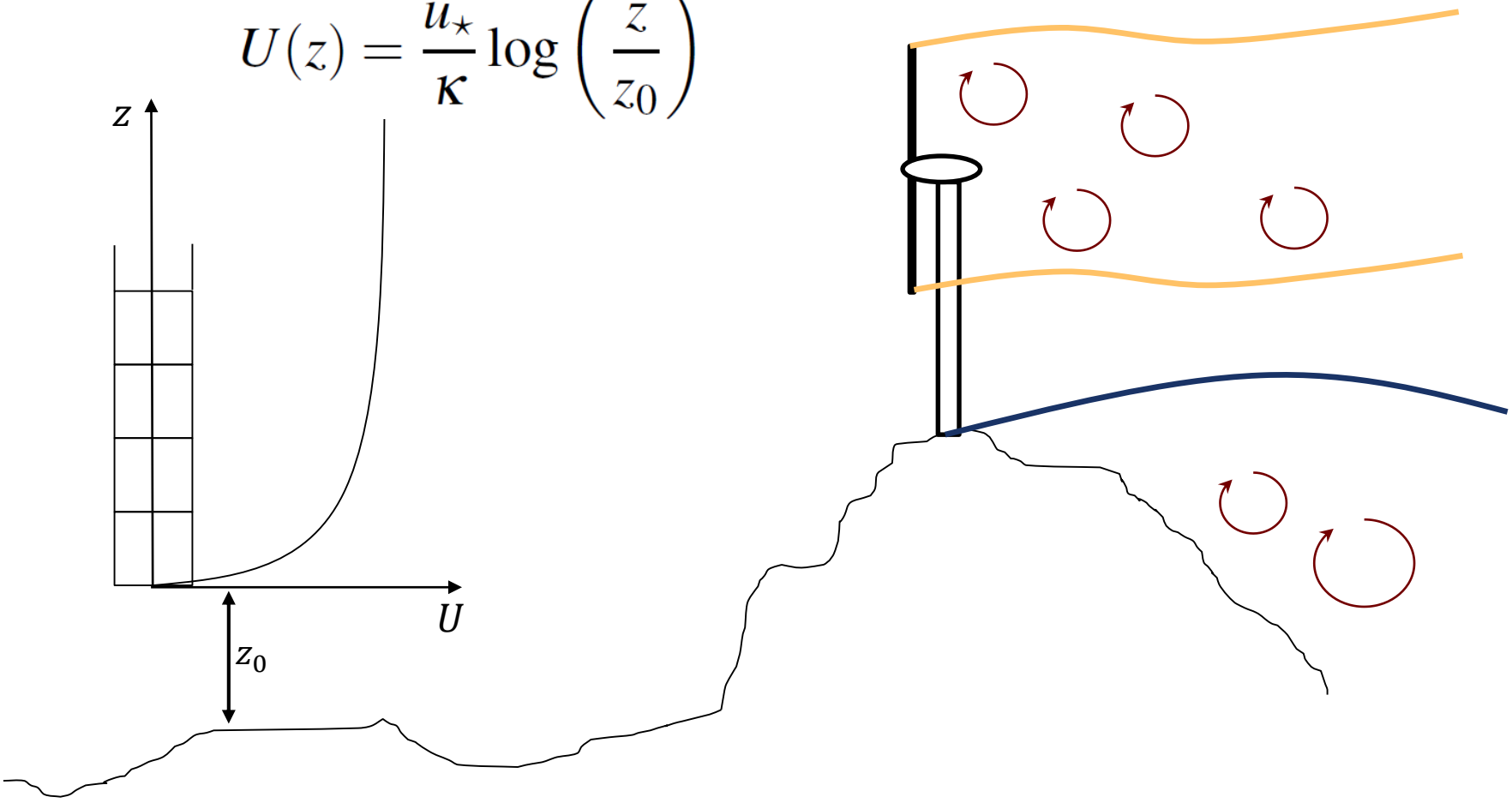
- Steady-state incompressible RANS
- QUICK scheme solved convective terms
- SIMPLE the pressure-linked terms

Modeling the induction zone in complex terrain



Modeling the induction zone in complex terrain

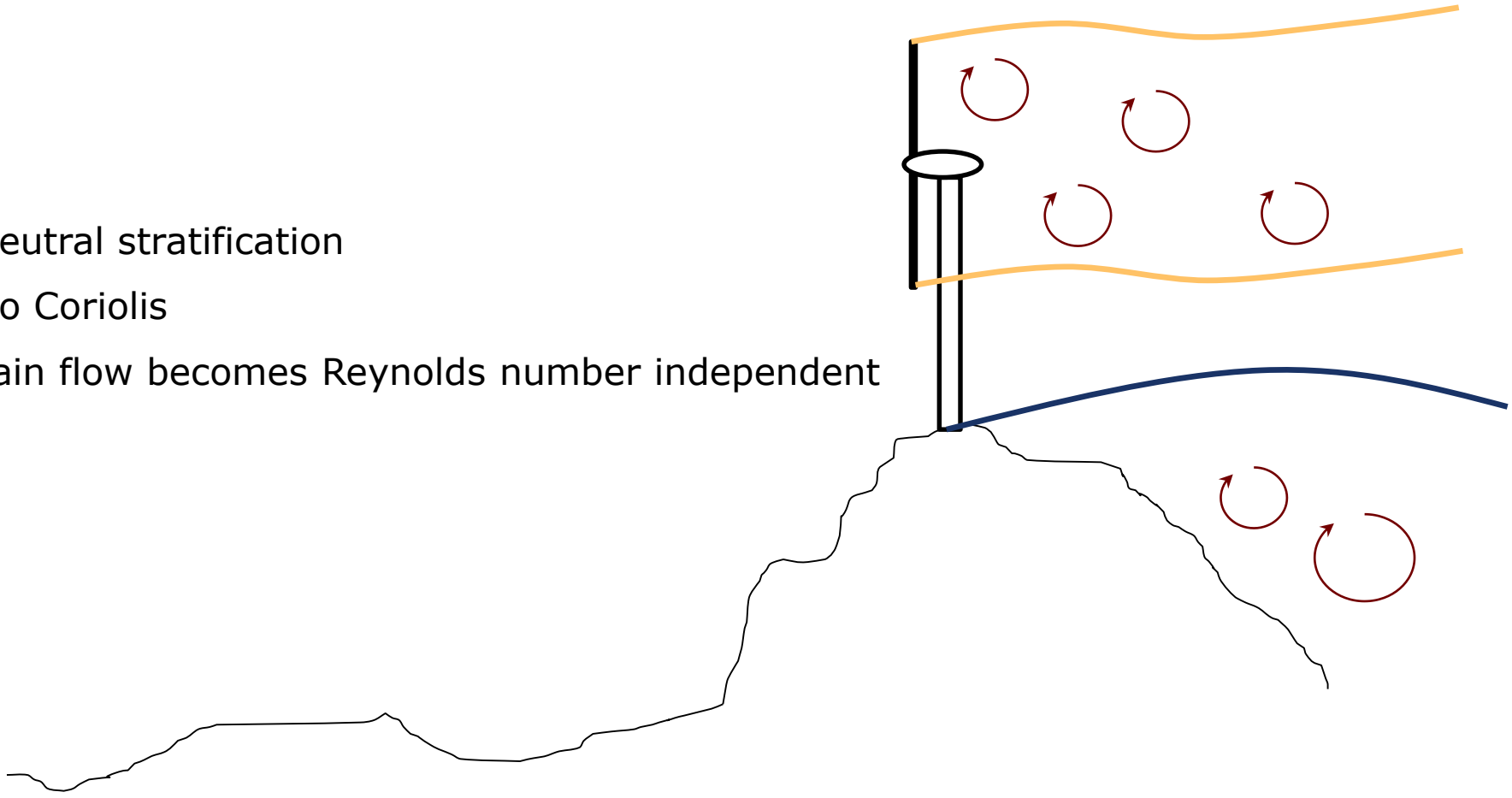
$$U(z) = \frac{u_\star}{\kappa} \log\left(\frac{z}{z_0}\right)$$



Modeling the induction zone in complex terrain

- Neutral stratification
- No Coriolis

Terrain flow becomes Reynolds number independent



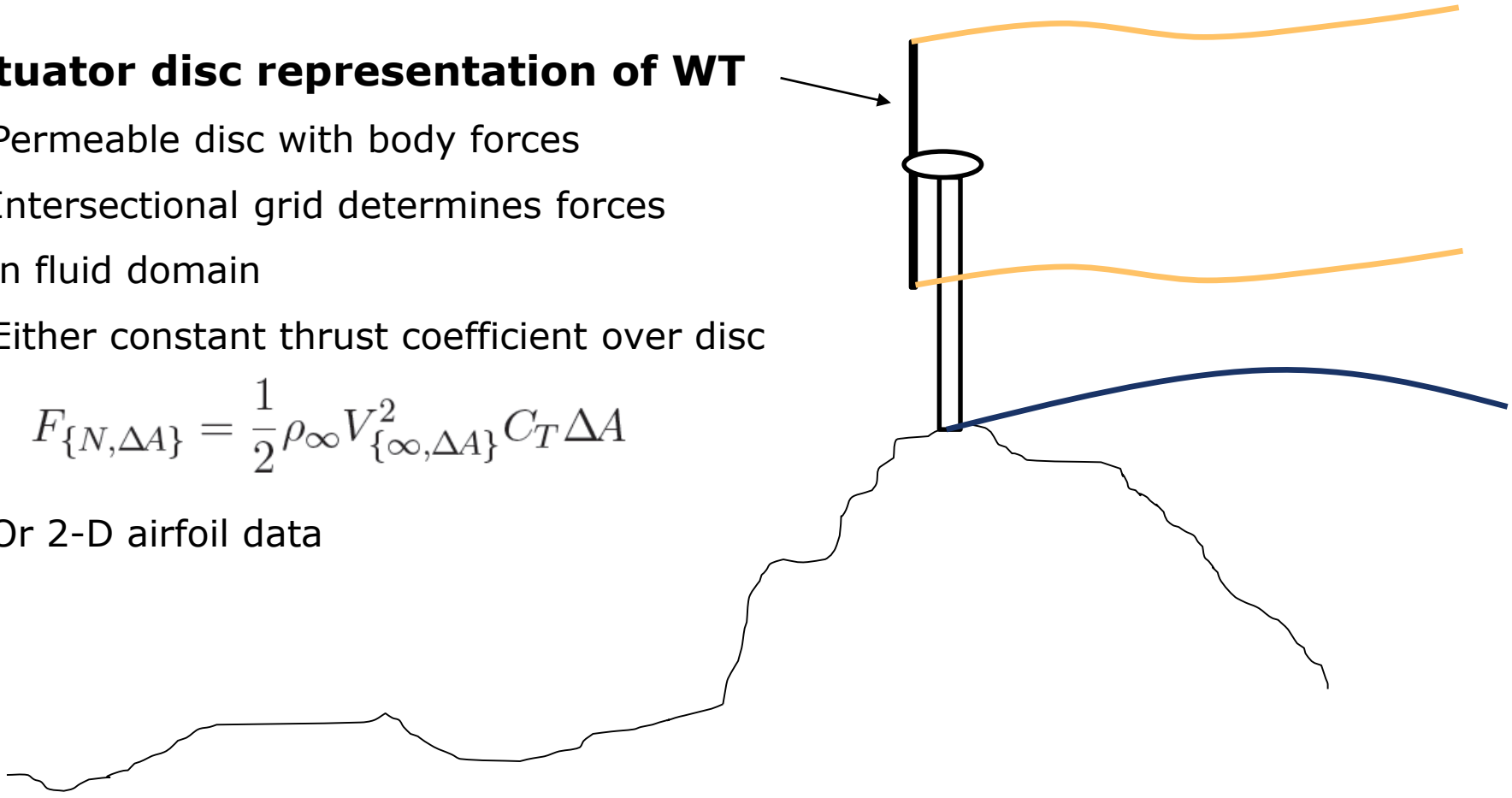
Modeling the induction zone in complex terrain

Actuator disc representation of WT

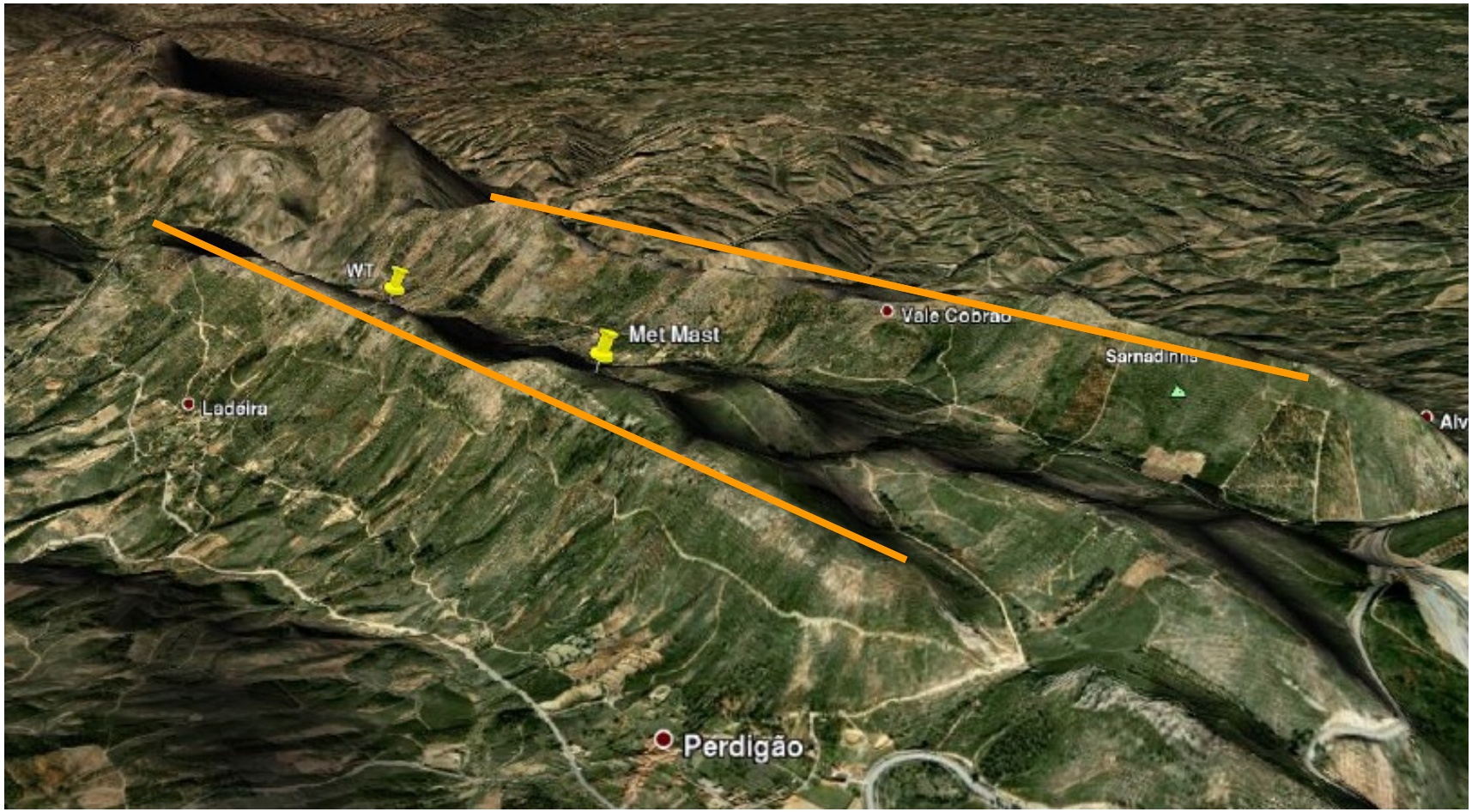
- Permeable disc with body forces
- Intersectional grid determines forces in fluid domain
- Either constant thrust coefficient over disc

$$F_{\{N,\Delta A\}} = \frac{1}{2}\rho_\infty V^2_{\{\infty,\Delta A\}} C_T \Delta A$$

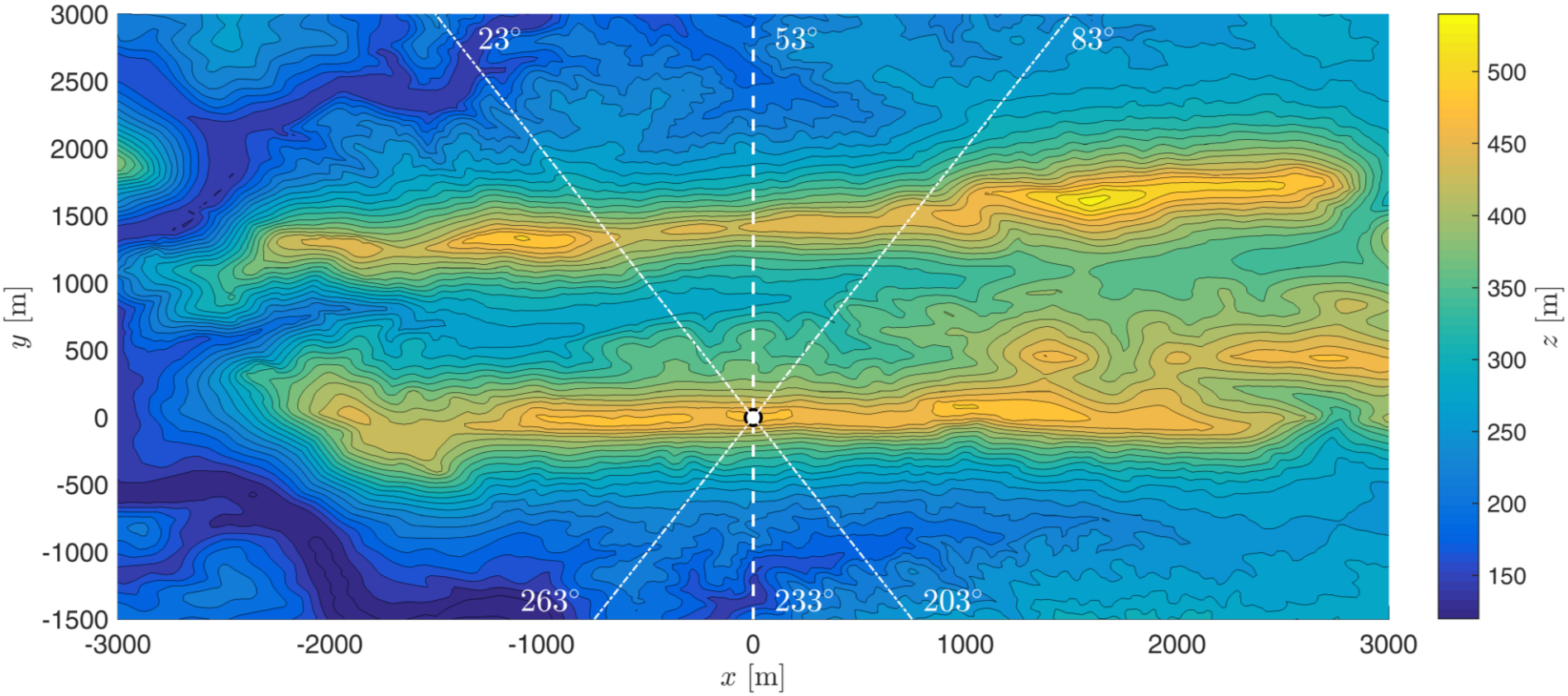
- Or 2-D airfoil data



Complex terrain test case: Perdigão



Complex terrain test case: Perdigão

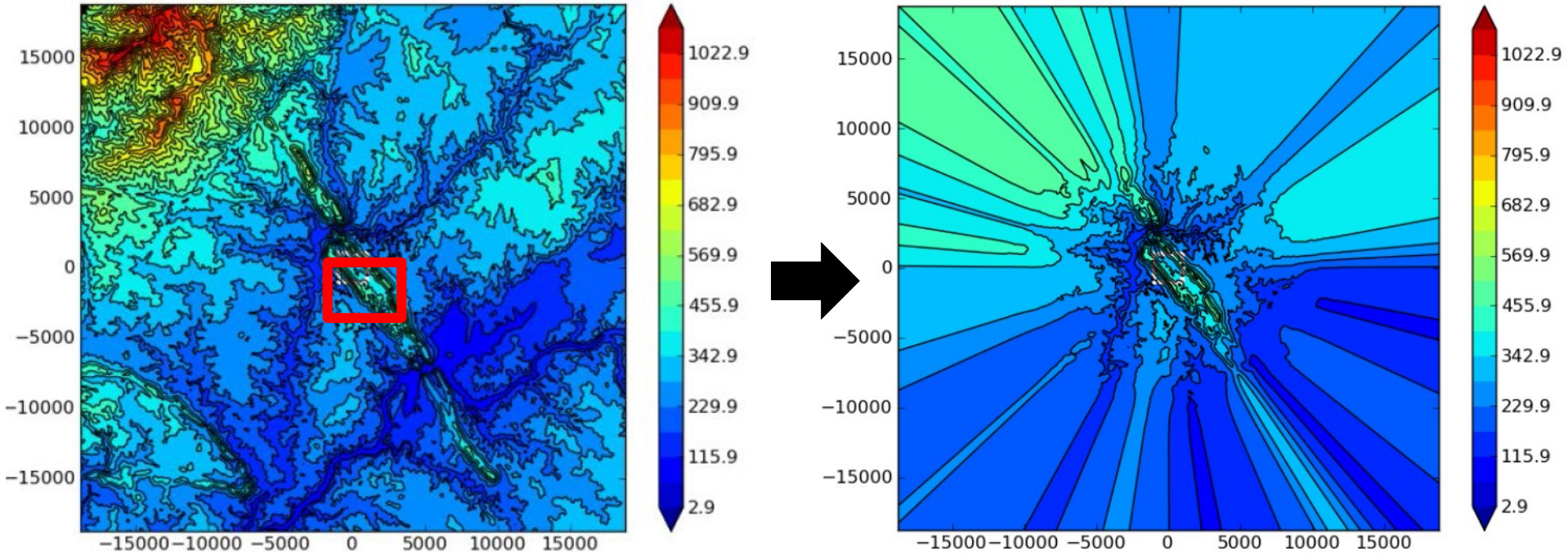


Complex terrain test case: Perdigão

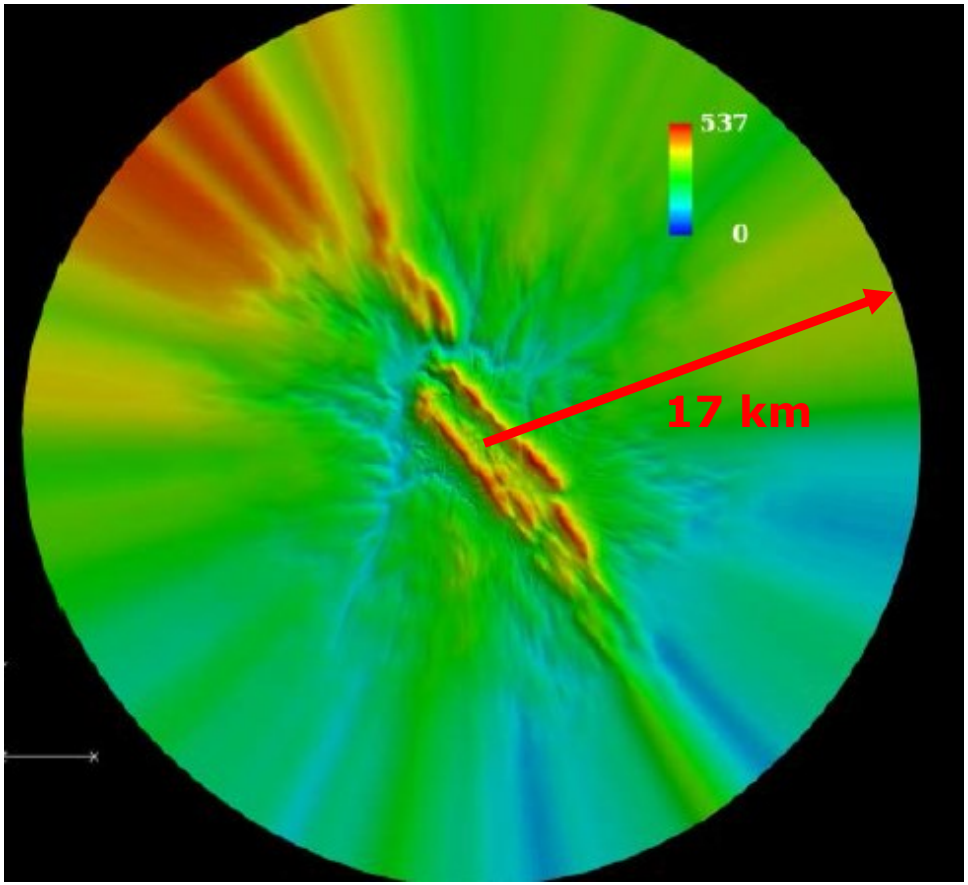
Terrain treatment for mesh generation

Far-field terrain and reference roughness

- Smoothed over grid spacing and towards the edges of the domain



The domain



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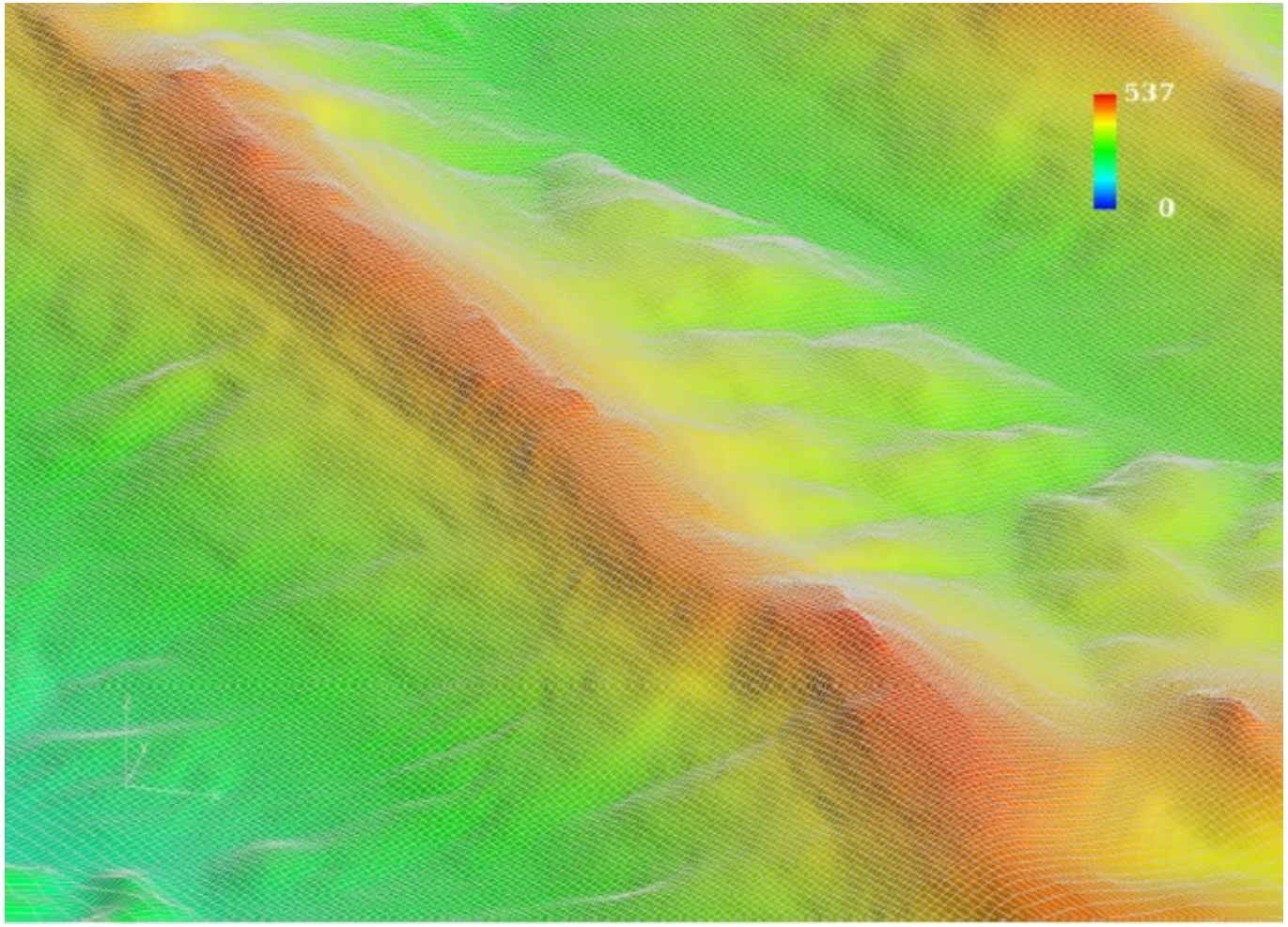
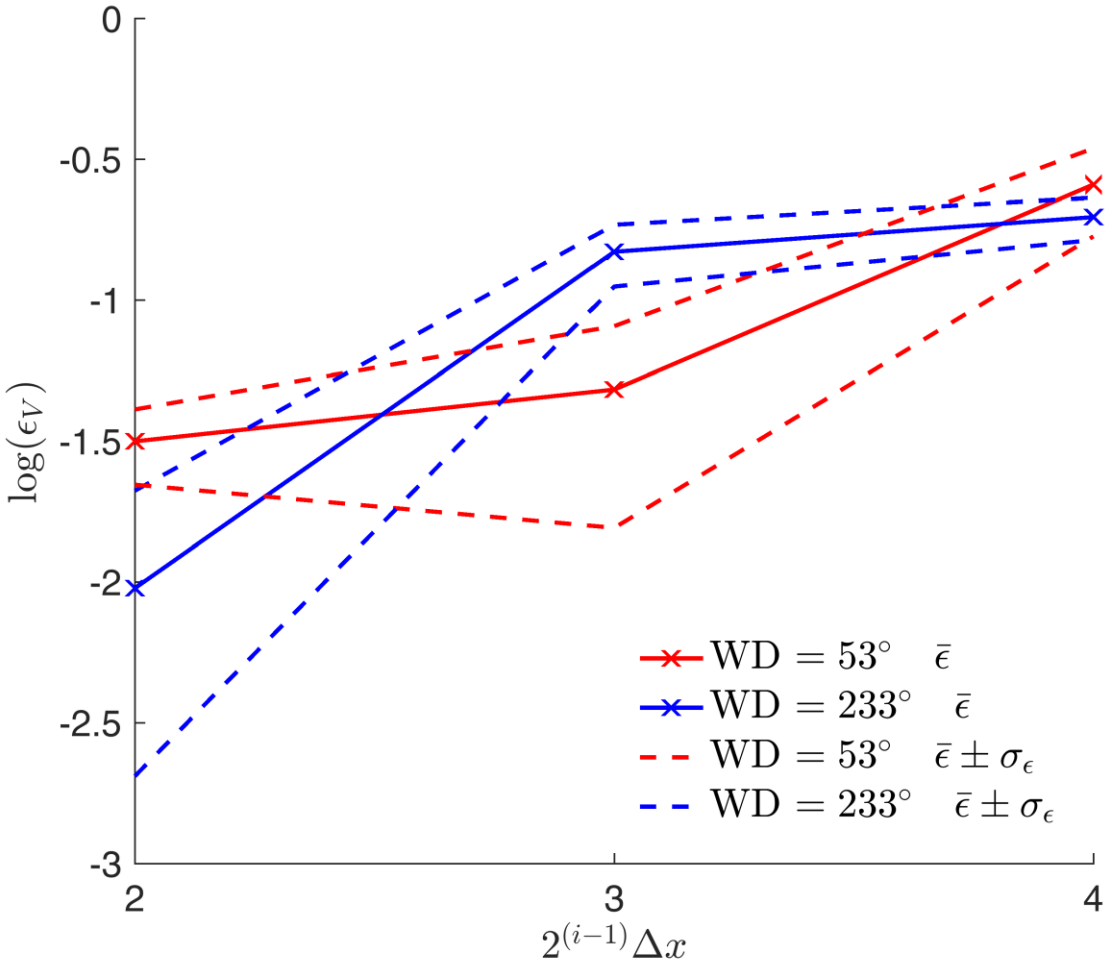


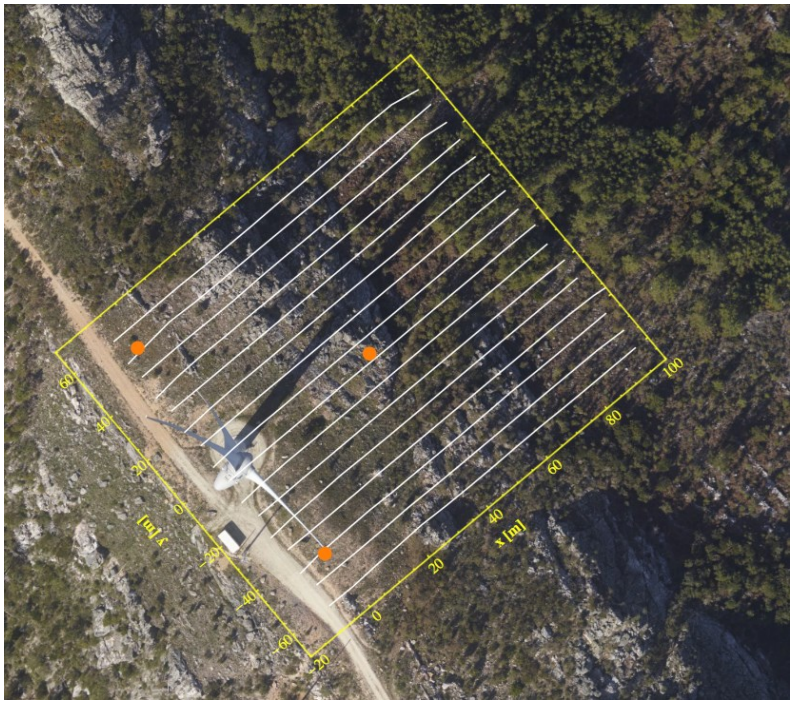
Grid sensitivity

$$\Delta x = \frac{R}{16} = 2.56\,m \longrightarrow 2.13M\ cells$$



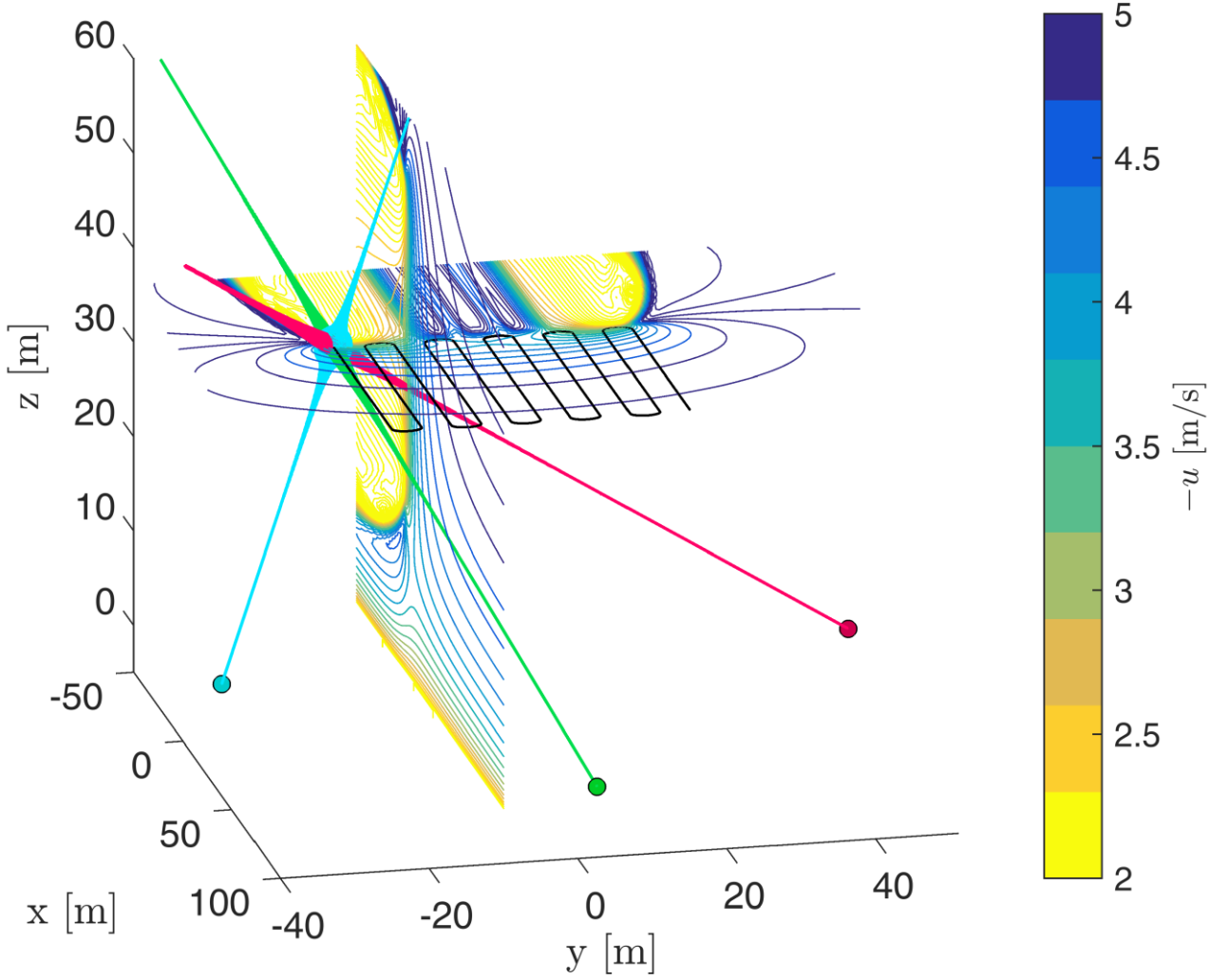
Measurements at Perdigão

- Synchronised lidar measurements around WT and valley



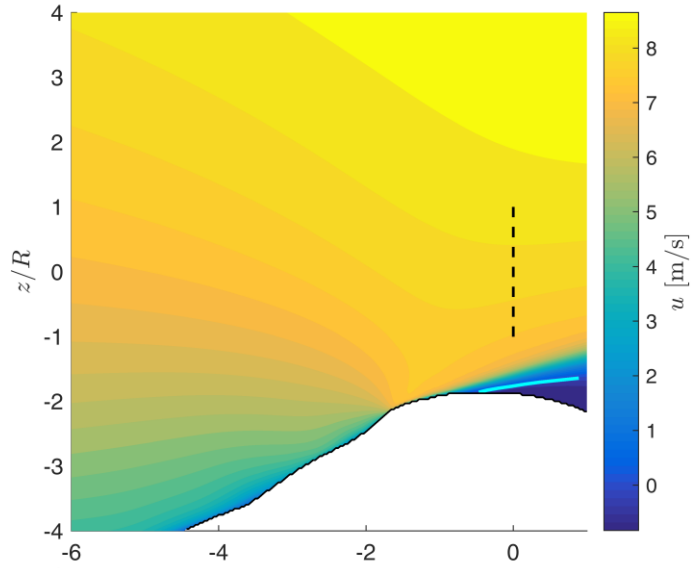
Measurements at Perdigão

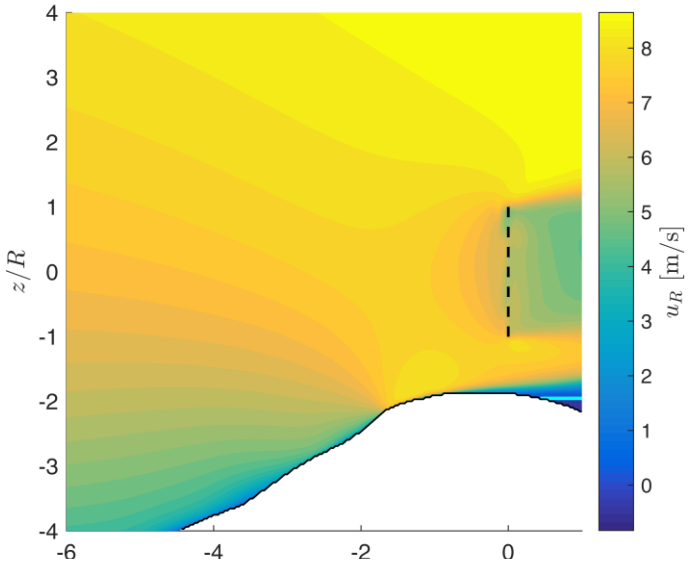
Synchronised triple-lidar



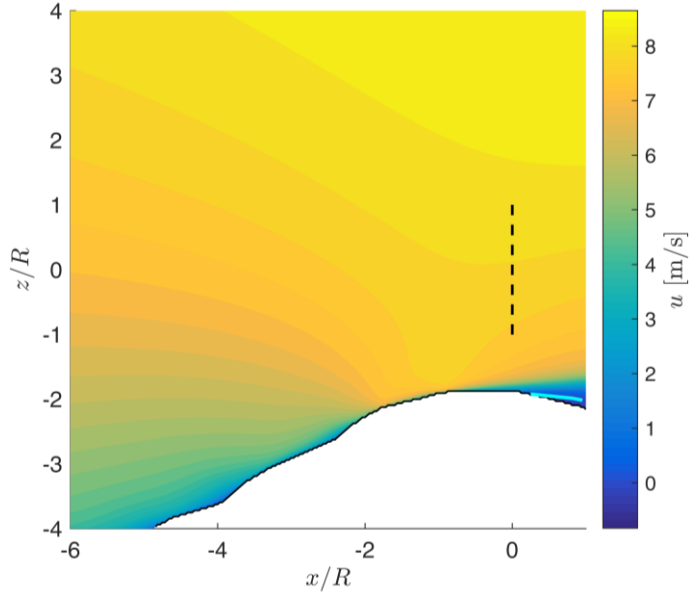
CFD Results

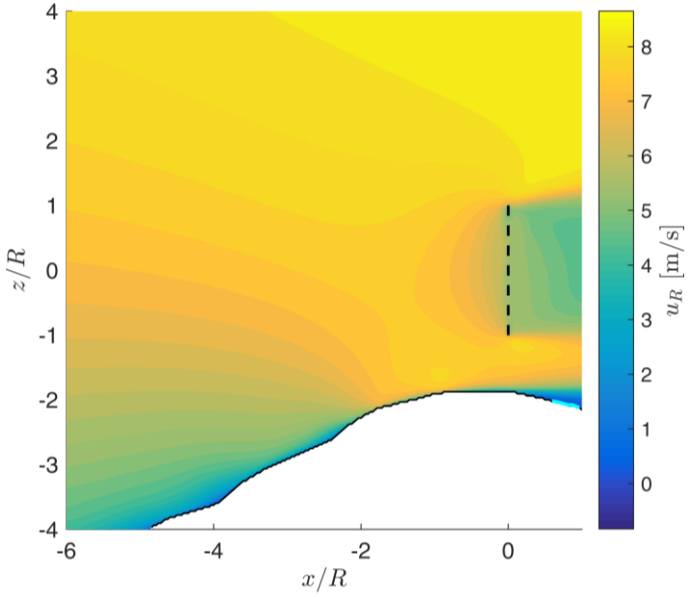
218°





263°



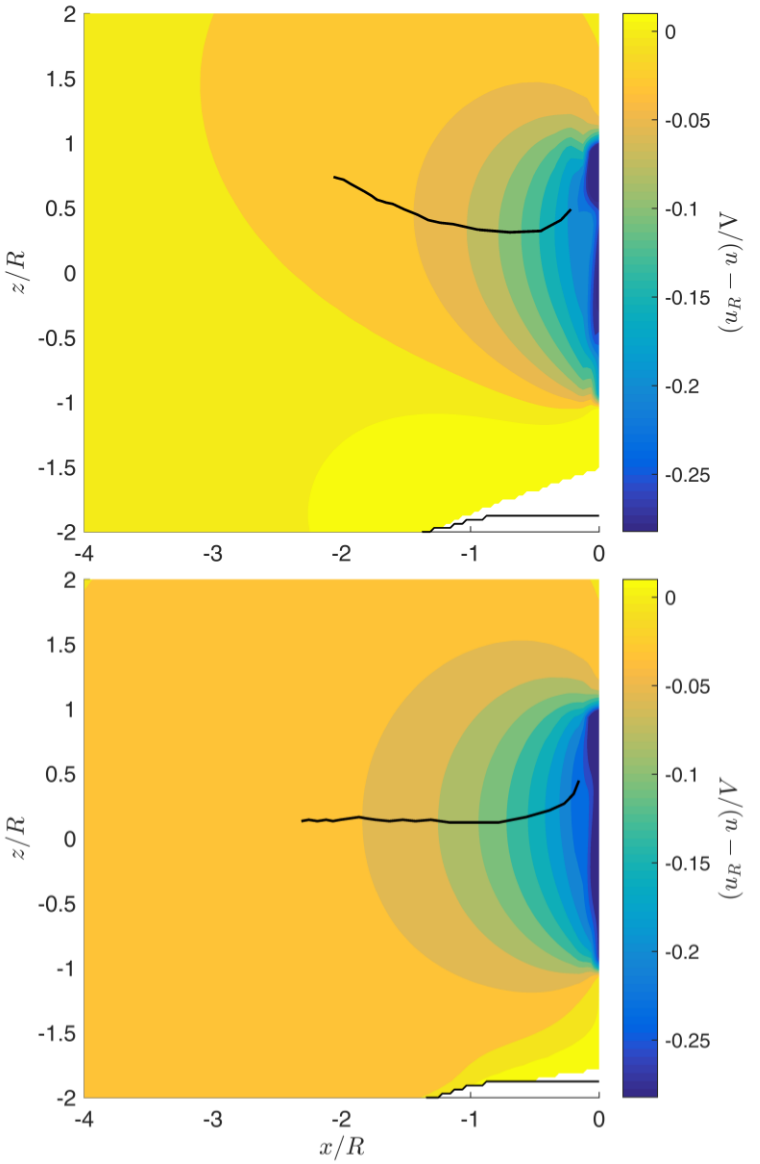


CFD Results

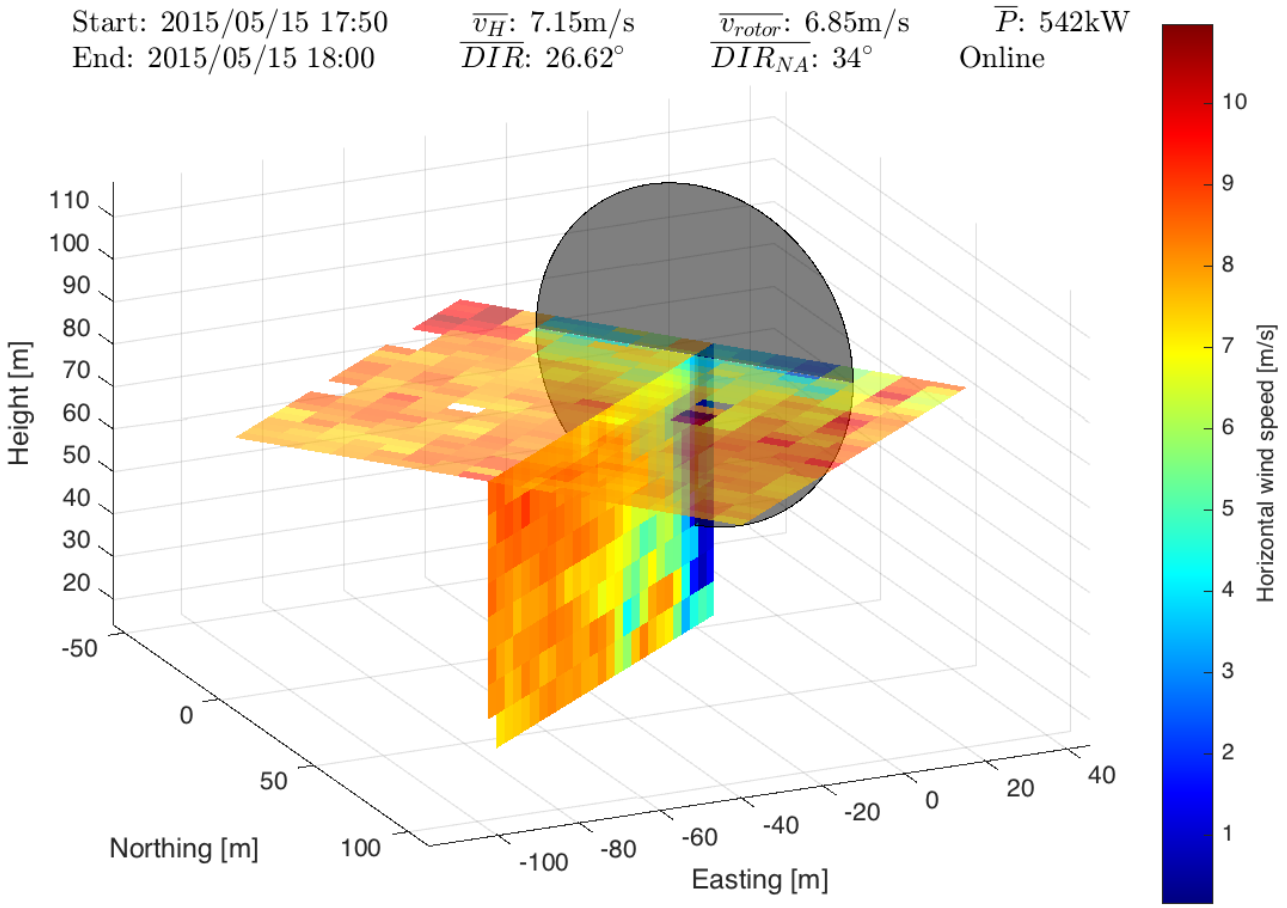
Wind directions

218°

263°

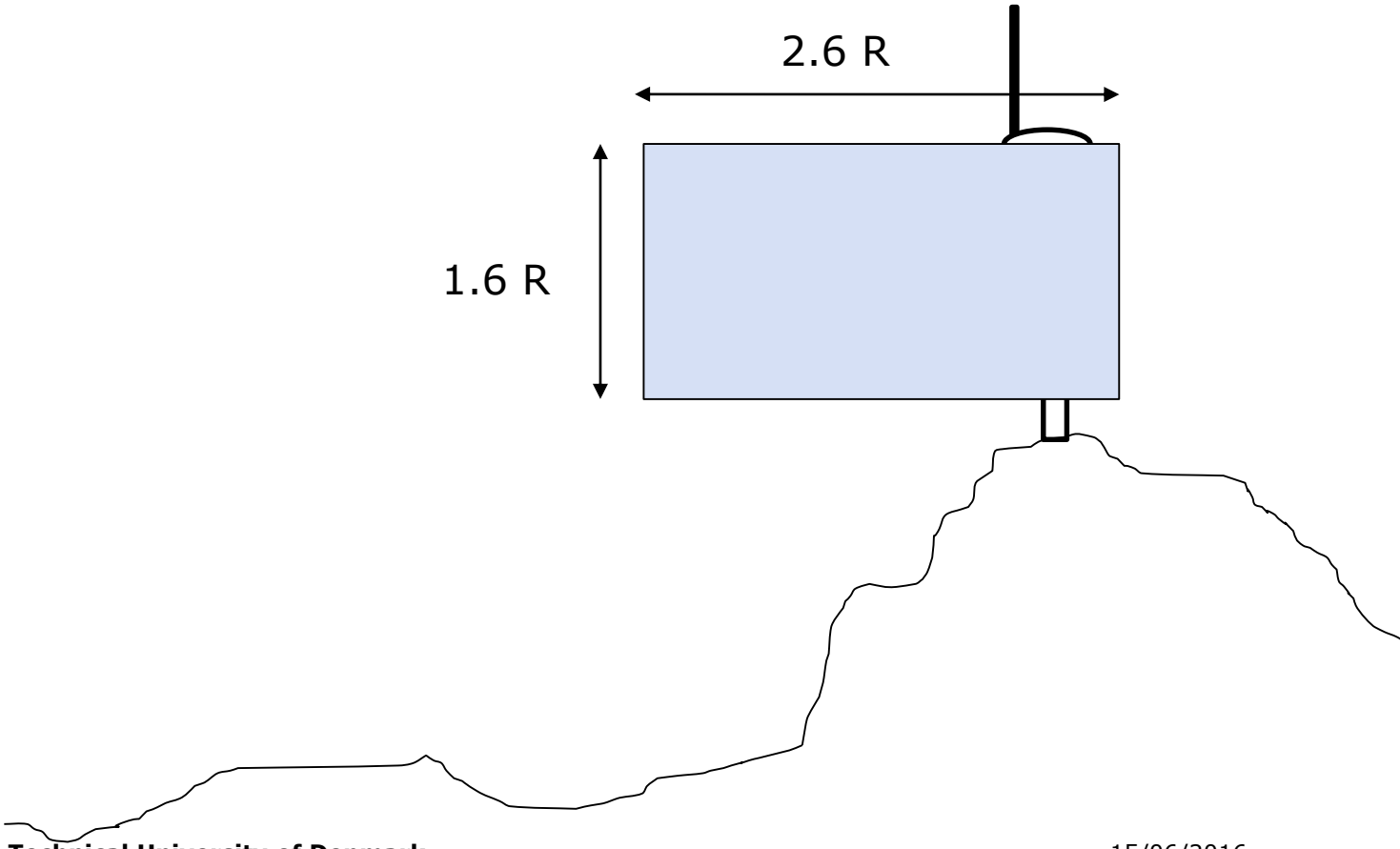


Triple-lidar results

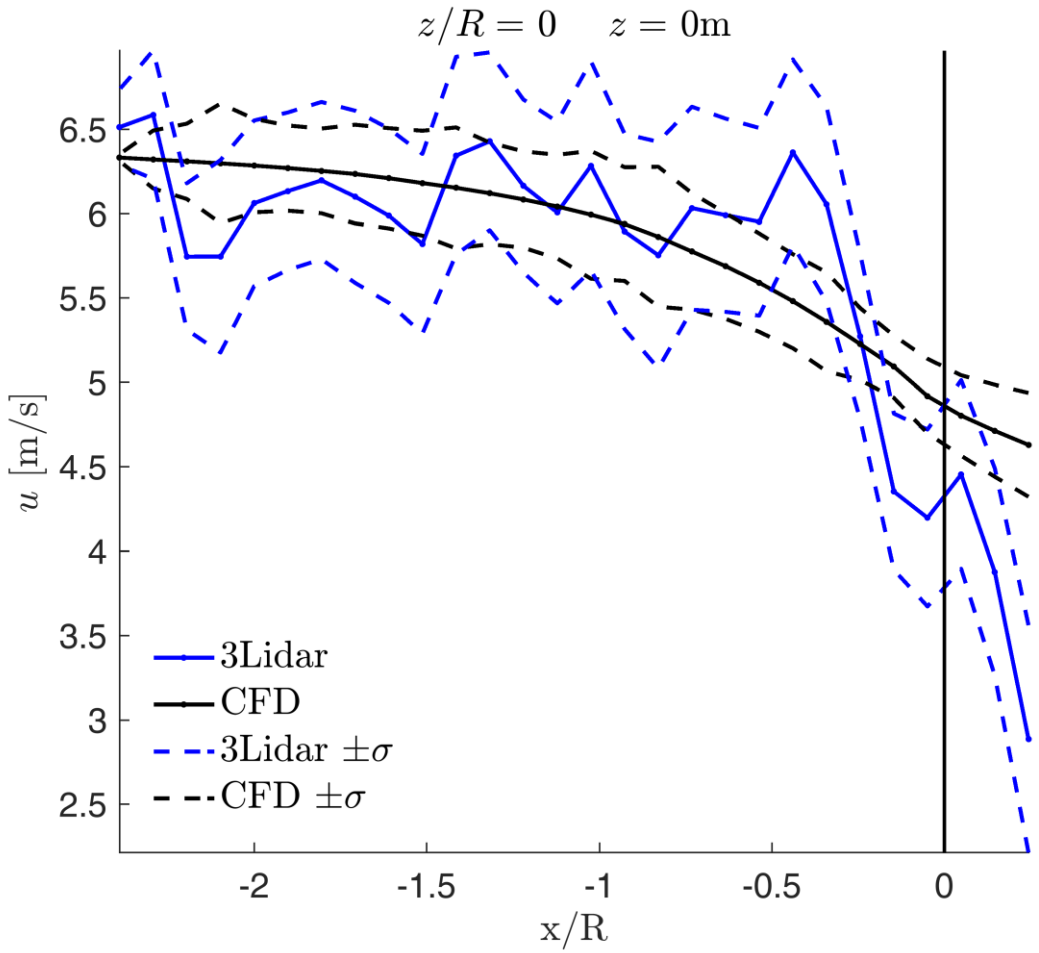


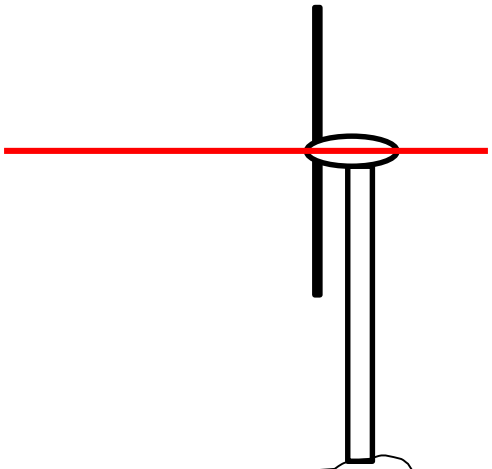
By R. Menke

Comparaison triple-lidar and CFD

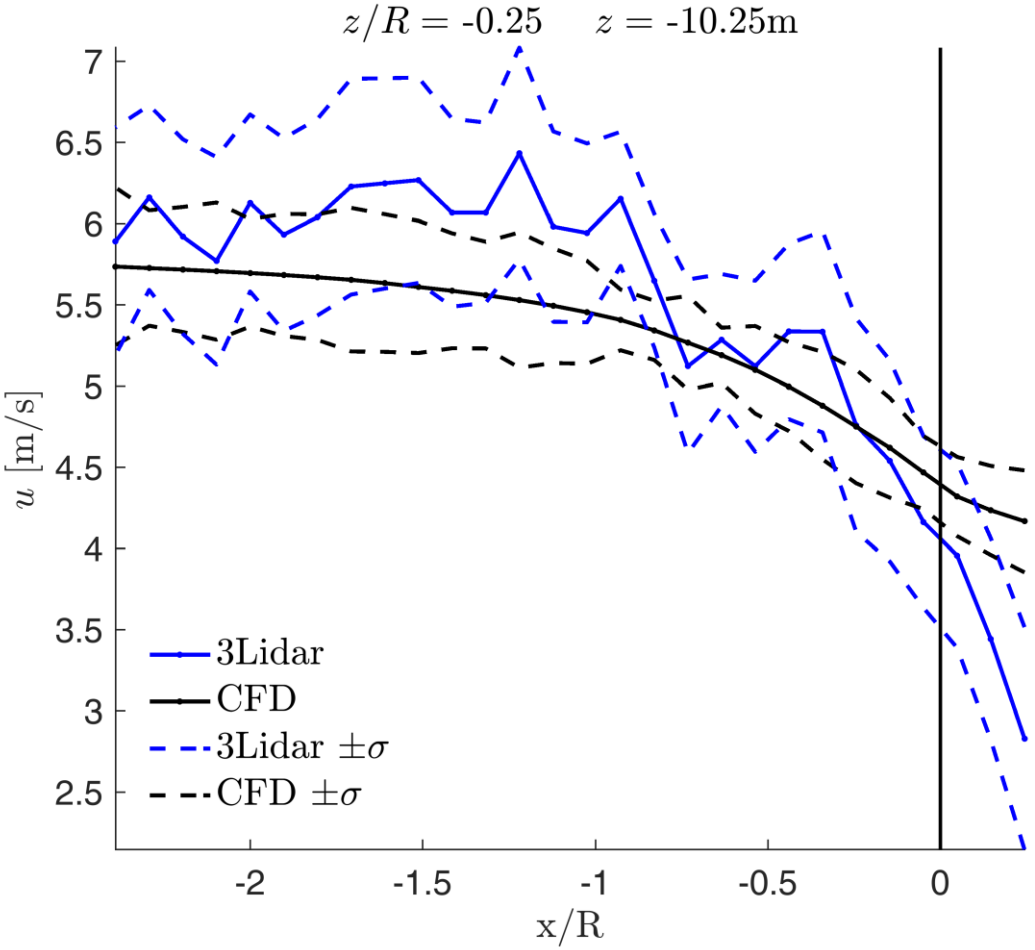


Comparaison triple-lidar and CFD

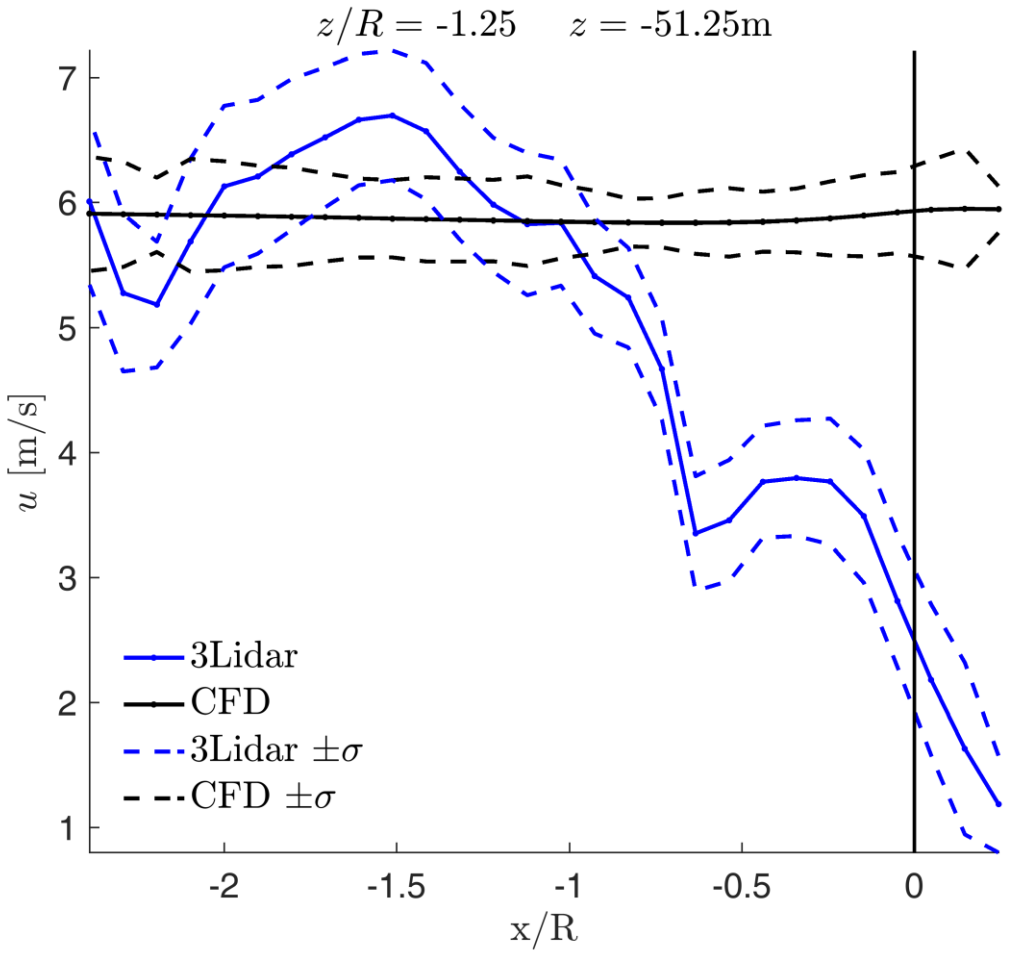


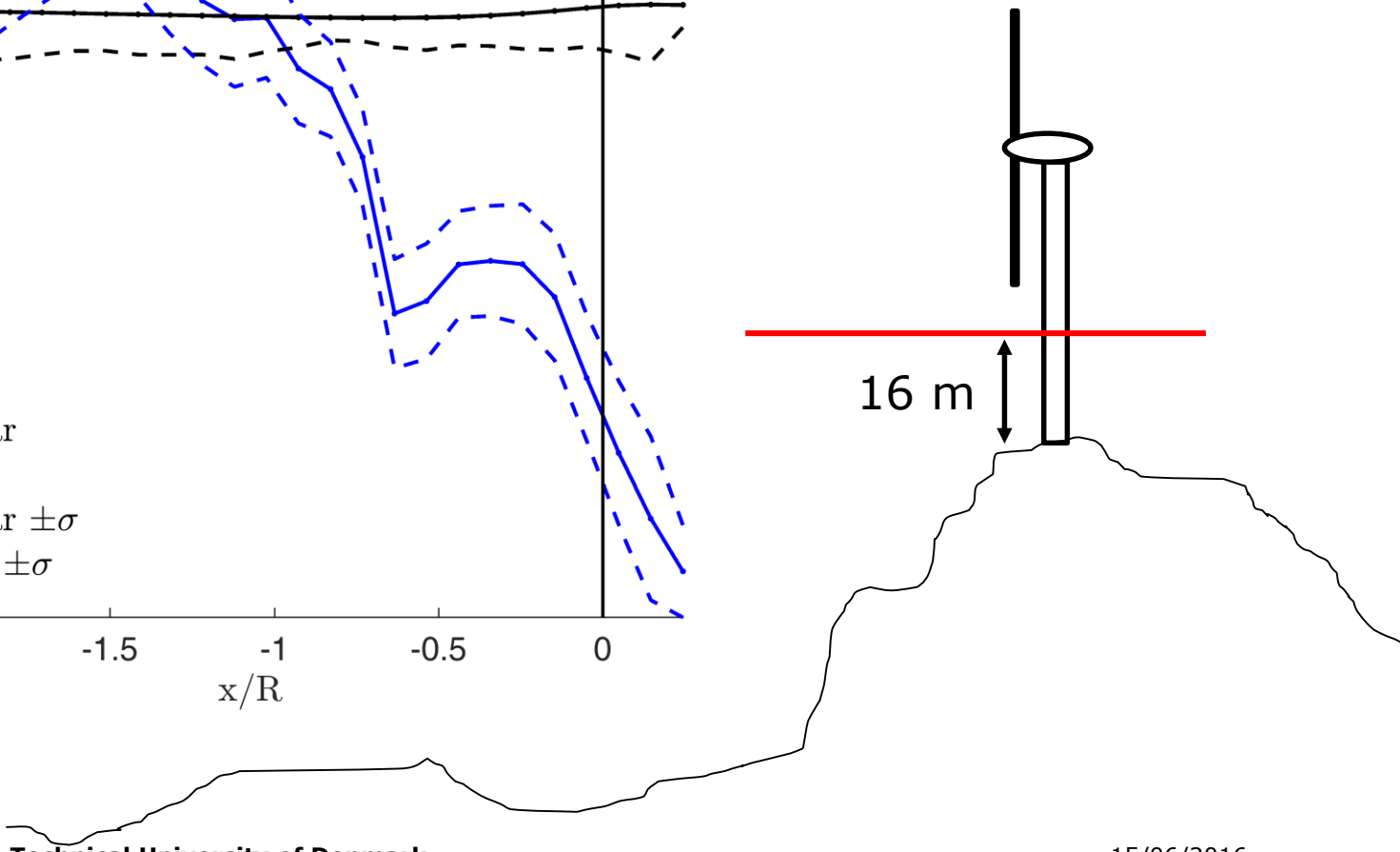


Comparaison triple-lidar and CFD



Comparaison triple-lidar and CFD





Conclusion

- Automated complex terrain simulations incorporating several pre-processing steps
- Triple-lidar shows high potential for complex flow measurements
- Large uncertainty in inflow conditions needs to be accounted for
- Steady-state RANS seems to capture induction zone correctly
- Computational uncertainty from:
  - Stratification
  - Roughness
  - Turbine
  - Terrain

Future work

- Investigate more measurement periods
- Include variability of wind direction into validation methodology
- Include stratification

Thanks for your attention!

Questions?